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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

EXPLANATION OF SPECIAL OXFORD SHEET.

THE GEOLOGY
OF THE COUNTRY AROUND
OXFORD.

By T. I. POCOCK, M.A.

WITH CONTRIBUTIONS BY

H. B. WOODWARD, F.R.S., AND G. W. LAMPLUGH, F.R.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

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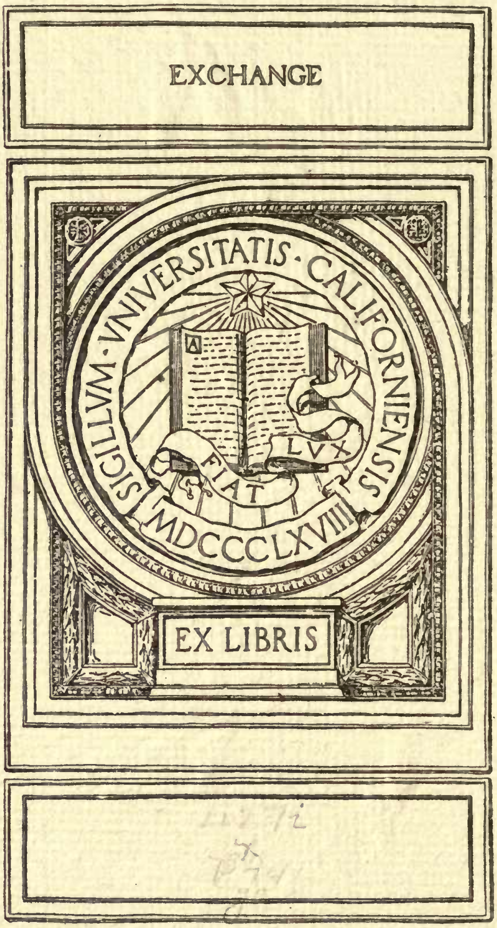

41

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EXCHANGE

PREFACE.

THE original geological survey of the area included in the new Oxford Sheet was carried out during the years 1857 to 1863 by Messrs. E. Hull, H. Bauerman, W. Whitaker, T. R. Polwhele, and A. H. Green. Their work was published on the Old Series Sheets 13, 45 S.W. and 45 S.E., and in accompanying Explanatory Memoirs. Some revisions at Islip (45 S.E.) were made in 1867 by H. W. Bristow.

The re-survey on the six-inch scale was commenced in 1896 by the late Mr. John Hopwood Blake and continued until the time of his death early in 1901. It was afterwards decided to complete the field-work over an area sufficient for the publication of a map with Oxford as a centre, and Mr. T. I. Pocock was deputed to do this work under the superintendence of Mr. H. B. Woodward, who personally surveyed portions of the country near Wheatley. Aid was also given in the examination and revision of the Lower Cretaceous areas by Mr. G. W. Lamplugh, whose observations have led to a separation of the freshwater Shotover Sands, now regarded as of Wealden age, from the marine Lower Greensand with which they were formerly grouped by the Geological Survey.

The preparation of the Memoir was entrusted to Mr. Pocock, who has dealt very fully with the Pleistocene and Recent deposits, to which he has given especial attention. The chapters dealing with the Jurassic Rocks have been partly written by Mr. Woodward, those on the Lower Cretaceous rocks have been contributed by Mr. Lamplugh, and that on the Upper Cretaceous rocks is based on the published observations of Mr. Jukes-Browne.

Owing to the resignation of Mr. Pocock in 1906, a larger share of the work than was expected has fallen to Mr. Woodward, who has written the Introductory Chapter and prepared the Appendix.

We are indebted to Mr. T. Codrington for a section of the railway-cutting near Horsepath, and to Mr. W. W. Fisher, Mr. R. H. Tiddeman, of Oxford, and Mr. George Winship, of Abingdon, for records of well-borings.

The fossils collected during the progress of the geological survey have been named in the Palæontological Department.

A list of the six-inch geological maps with the authors and dates of survey is appended. MS. copies of these maps are deposited in the Office for public reference.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, *Jermyn Street, London,*
5th November, 1907.

List of Six-inch Geological Maps.

Berkshire.

6 S.W. (Oxford 39 S.W.). Bessels Leigh. By J. H. Blake, 1899, and T. I. Pocock, 1904.
9 N.W. Hinton Waldrist, Kingston Bagpuize. By J. H. Blake, 1899.
N.E. Fyfield, Marcham. By J. H. Blake, 1899, and T. I. Pocock, 1905.

Buckinghamshire.

26 S.E. (Oxford 28 S.E.). Muswell Hill. By H. B. Woodward, G. W Lamplugh, and T. I. Pocock, 1904–05.
S.W. (Oxford 28 S.W.). Ot Moor. By T. I. Pocock, 1905.
27 S.W. (Oxford 29 S.W.). Brill. By H. B. Woodward and G. W. Lamplugh, 1904–05.
31 N.E. (Oxford 34 N.E.). Oakley. By H. B. Woodward and T. I. Pocock, 1904–05.
S.E. (Oxford 34 S.E.). Worminghall, Waterperry. By H. B. Woodward, 1904–05.
32 N.W. (Oxford 35 N.W.). Ixhill. By H. B. Woodward, 1905.
S.W. (Oxford 35 S.W.). Little Ickford. By H. B. Woodward, 1905.

Oxfordshire.

26 S.W. Wilcote, North Leigh. By T. I. Pocock, 1904.
S.E. Bladon, Church Hanborough. By T. I. Pocock, 1904.
27 S.W. Begbroke, Kidlington. By T. I. Pocock, 1904.
S.E. Islip, Oddington. By T. I. Pocock, 1905.
32 N.W. Eynsham Hall. By T. I. Pocock, 1904.
N.E. (Berks 1 N.E.). Eynsham, Cassington. By T. I. Pocock, 1904.
S.W. South Leigh, Hardwick. By T. I. Pocock, 1904.
S.E. (Berks 1 S.E.). Swinford. By J. H. Blake, 1897, and T. I. Pocock, 1904.
33 N.W. (Berks 2 N.W.). Yarnton. By J. H. Blake, 1899, and T. I. Pocock, 1904.
N.E. Woodeaton, Elsfield. By J. H. Blake, 1898, and T. I. Pocock, 1904.
S.W. (Berks 2 S.W.). Wytham and Binsey. By J. H. Blake, 1898, and T. I. Pocock, 1904.
S.E. N. Oxford and Headington. By J. H. Blake, 1898, and T. I. Pocock, 1905.
34 N.W. Stanton St. John, Beckley, and Studley. By T. I. Pocock, 1904–05.
S.W. Forest Hill and Holton. By J. H. Blake, 1897; H. B. Woodward, G. W. Lamplugh, and T. I. Pocock, 1904–05.
38 N.W. Brighthampton and Standlake. By J. H. Blake, 1897, and T. I. Pocock, 1904.
N.E. (Berks 5 N.E.). Stanton Harcourt, Northmoor and Eaton. By J. H. Blake, 1897, and T. I. Pocock, 1904.
S.W. (Berks 5 S.W.). Shifford. By T. I. Pocock, 1904.
S.E. (Berks 5 S.E.). Appleton. By J. H. Blake, 1897, and T. I. Pocock, 1904.
39 N.W. (Berks 6 N.W.). Cumnor. By J. H. Blake, 1897, and T. I. Pocock, 1904.
N.E. (Berks 6 N.E.). S. Oxford, Cowley. By J. H. Blake, 1897, and T. I. Pocock, 1904.
S.E. (Berks 6 S.E.). Littlemore, Sandford-on-Thames. By J. H. Blake, 1899, and T. I. Pocock, 1905.
40 N.W. Wheatley, Horsepath. By J. H. Blake, 1897. H. B. Woodward and G. W. Lamplugh, 1904.
N.E. Waterstock, Tiddington. By J. H. Blake, 1898, and H. B. Woodward, 1904–05.
S.W. Garsington, Denton and Toot Baldon. By J. H. Blake, 1897, and H. B. Woodward, 1907.
S.E. Great Milton, Great Haseley. By J. H. Blake, 1897, and H. B. Woodward, 1905.
41 N.W. Albury. By A. J. Jukes-Browne, 1885, and H. B. Woodward, 1905.
S.W. Latchford. By J. H. Blake, 1898, and H. B. Woodward, 1905.
45 N.W. (Berks 10 N.W.). Abingdon. By J. H. Blake, 1896, and T. I. Pocock, 1905.
N.E. (Berks 10 N.E.). Nuneham Courtenay. By A. J. Jukes-Browne, 1887, J. H. Blake, 1897, T. I. Pocock, 1905, and H. B. Woodward, 1907.
46 N.W. March Baldon. By A. J. Jukes-Browne, 1886, J. H. Blake, 1899, and H. B. Woodward, 1907.
N.E. Stadhampton. By J. H. Blake, 1899.
47 N.W. Easington. By A. J. Jukes-Browne, 1886.

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Geological Formations.

The geological formations represented at the surface are as follows:—

				Thickness. Ft.
Recent and Pleistocene		Alluvium		15
		Brickearth		10
		Valley gravel		30
		Plateau gravel		20
Upper Cretaceous		Upper Greensand		90
		Gault (clay)		200
Lower Cretaceous		Lower Greensand		50
		Wealden—Shotover Sands (with clay, and ironstone)		40
Jurassic	Upper Oolitic	Purbeck Beds (clay and limestone)		15
		Portland Beds	Limestone and sands	40
			Sands and Hartwell Clay	30
		Kimeridge Clay		100
	Middle Oolitic	Corallian Beds	Coral Rag and Oolite Calcareous grit and sands Ampthill Clay	50 to 100
		Oxford Clay and Kellaways Beds (sands and clay)		450
	Lower Oolitic	Cornbrash (limestone)		9 to 17
		Forest Marble (clay and limestone)		12 to 35
		Great Oolite (white limestone, oolite and marl), with Upper Estuarine Series		130
		Inferior Oolite (limestone)		30

Strata proved by Boring.

Strata belonging to the Lias occur not far below the surface in the north-western portion of the area, and have been proved in borings at Witney (just beyond the western margin of the sheet), and at Oxford. The depth at which the Palæozoic floor might be reached is a subject of considerable importance in connection with the possible occurrence of productive Coal-measures.

The deep boring at Wytham, which was completed in 1829, was made probably in search of coal. As stated by John Phillips, "the operation was conducted by E. Bagnall, Mine Agent, Baskerville House, Birmingham," and "the terms employed by the workmen are used in the coalfields of Staffordshire." The boring was carried to a depth of 633 feet, and probably reached the Lower Lias. No specimens have been preserved.

Other futile trials, made early in nineteenth century in the Kimeridge Clay at Bagley Wood, south of Oxford, and at Brill, and in the Oxford Clay of Eynsham Heath, were not carried to a sufficient depth to be of any practical value; they were made in ignorance, and simply brought loss to the speculators.[1]

Dealing generally in 1871 with the possibility of finding coal, Phillips concluded "that coal-measures, if they exist, would not be situated at an inaccessible depth in the country north of Oxford; but there is no good reason for selecting that or any other situation in the upper drainage of the Thames for an experiment, excepting that there the Upper Oolites and Chalk are not to be encountered in the sinking."[1]

---

[1] Phillips, "Memoirs of William Smith," pp. 66, 67; and C. S. Read, *Journ. Roy. Agric. Soc.*, vol. xv., 1854, p. 197.

Soon after the date when Phillips penned the above remarks, his views were substantially confirmed by the boring made (1875-77) at Burford Signet, south of Burford, seven miles west of Witney, and about sixteen miles west of Oxford. There Coal-measures were reached at a depth of 1,184 feet beneath Oolites, Lias, and New Red Marl. More recently Coal-measures have been proved near Batsford, in Gloucestershire, at a distance of 25 miles north-west of Oxford, and at a depth of 1,021 feet below the surface. Silurian strata were found beneath them.[2]

The evidence obtained on the ground near Fawler, as well as that of later borings at Witney and Oxford, tends to show that the Upper and Middle Lias become attenuated towards Oxford. In the record of the Witney boring there was no indication of any mass of Upper Lias clay, and in the boring for the City Brewery at Oxford there was an entire absence of both Upper and Middle Lias. In the latter instance it is just possible that the bore-hole passed through a plane of faulting at the junction of the Inferior Oolite and Lower Lias; this is speculative, but not without some support when we look to the faults and flexures that bring up the Lower Oolites at Islip and Oddington. The important fact, however, remains, that Lower Lias was reached in Oxford at the depth of 422 feet 6 inches, and if the thickness of Lower Lias and New Red rocks proved at Burford, is maintained without increase so far eastwards, the Palæozoic floor would be reached at a depth of about 1,340 feet below the city. The natural inference from the known data, however, would be that the Lower Lias and New Red rocks diminish also eastward, and that the older rocks might be reached at a depth of about 1,000 feet. (See Fig. 1.)

Thus although Lias is not exposed in the area of the Oxford map, it was inferred to occur at a depth of 448 feet in the boring at Wytham, and has since been proved to be present under the city of Oxford. (See p. 125.)

In his account of the "Mineral Water discovered in sinking the artesian well at St. Clement's, Oxford," Prestwich concluded "that the water has its origin in the New Red Sandstone, and not in the Oolitic or Liassic strata, as would otherwise, from the depth of the boring, be the natural inference"; and he was inclined to adopt the view "that, while the Oolitic strata become much reduced, the whole of the Liassic strata, as they range underground from Cheltenham to Oxford, thin out, so that the Oolitic strata here immediately overlie the New Red Sandstone."[1]

---

[1] "Geology of Oxford and the Valley of the Thames," 1871, pp. 296, 297; see also Hull, *Quart. Journ. Geol. Soc.*, vol. xvi., 1860, p. 80.

[2] Those who desire further to consider this subject should consult the Final Report of the Royal Commission on Coal Supplies, part ix.—Resources of the Concealed and Unproved Coalfields of the United Kingdom, 1905 (Reports by A. Strahan and others), see pp. 16, 36, &c. See also W. B. Dawkins, *Rep. Brit. Assoc.* for 1894, p. 647.

In the interpretation of the strata recorded at Wytham we ventured to differ from Prestwich, assigning 35 feet more to the Lias than he had done, and remarking "if this be true, the Lias probably does extend below Oxford."[2] The proof of the occurrence of Lower Lias at the City Brewery therefore confirms this inference.

The entire thickness of Lias at Chipping Campden, on the Northern Cotteswolds, was proved to be 1,361 feet; at Burford it does not exceed 627 feet. The records are as follows:—

	Mickleton, near Chipping Campden. Ft.	Burford. Ft. in.
Upper Lias	120	81 6
Middle Lias	280	98 1
Lower Lias	961	447 4

At Fawler, in the Evenlode Valley, not far from the north-western corner of the Oxford map, the Upper Lias is but 16 feet thick, and the Middle Lias about 40 feet.[3] We have no means of estimating the thickness of the Lower Lias

The following is a summary of the deeper borings in and adjacent to the area[4]:—

	Burford.	Witney.	Wytham.	Oxford City Brewery.	Oxford St. Clement's Brewery.	Kidlington.
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft.	Ft. in.
Alluvium	...	...	15 0	...	...	11 0
Gravel	...	...		30 0	...	
Oxford Clay and Kellaways Beds	...	...	258 0	210 0	265	2 0
Cornbrash ...	...	43 0	17 0	17 0	155[5]	13 0
Forest Marble ...	...		26 6	32 8		20 6
Great Oolite ...	62 6	141 6	96 0	88 0		141 6
Upper Estuarine Series	...			28 6		39 0
Inferior Oolite ...	27 8	30 0	35 6	16 4		7 0
Upper Lias ...	81 6	55 6+	14 6	...	...	233 0+
Middle Lias ...	98 1		170 6+	...	...	
Lower Lias ...	447 4			17 0+	...	
Rhætic and New Red Marl ...	466 11	...	...	...	...	...
Coal Measures ...	226 0	...	...	...	...	...
	1410 0	270 0	633 0	439 6	420	467 0

---

[1] Read before the Ashmolean Society, 1876.

[2] H. B. Woodward, "Jurassic Rocks of Britain," vol. iii. "Lias of England and Wales," p. 269.

[3] F. A. Bather, *Quart. Journ. Geol. Soc.*, xlii., p. 144.

[4] The details of the Burford boring were given in "Memoir on Jurassic Rocks of Britain," vol. iv.. pp. 303, 304; those of Witney, Wytham, and St. Clement's in vols. iv., pp. 372, 513, v., pp. 42, 43; and an abstract of the City Brewery boring, Oxford, in the "Summary of Progress" for 1898, p. 139.

[5] The thickness of rock-beds passed through has usually been given as 135 ft., but Prestwich ascertained at the St. Clement's Brewery that the depth was 155 ft. *Geol. Mag.*, 1876, pp. 238, 239.

Physical Features and Soils.

The strike of the Lower Oolites is from north-east to south-west, with a gentle south-easterly inclination of the strata. This is modified locally by the faulted anticline which brings in the Cornbrash and other rocks at Islip. With this exception the general strike and dip are maintained not only in the succeeding Oolitic strata, but in the Lower and Upper Cretaceous rocks which have transgressed unconformably on to some of the older divisions. The N.W. and S.E. faults that accompany the anticline disturbance at Islip, are continued by Forest Hill to Wheatley, and are probably connected with the inlying tract of Kimeridge Clay at Great Milton, and with the faulted tract of Shotover Sands at Great Haseley.

The Lower Oolites rise to nearly 450 feet in the north-western part of the area, and they lie a little over 30 feet beneath O.D. at Oxford, about eleven miles distant.

The features which characterise the outcrops of the successive strata are well marked, and at the same time, owing to the irregularities in the distribution of the overlapping Cretaceous strata, and the varied influences on the agents of denudation, considerable diversity of scenery has resulted.

The nature of the soil, as might be expected, is very changeable. The area comes within that described by Arthur Young[1] under two broad divisions, namely: (1) *The district of the Stonebrash* and (2) that of *Miscellaneous loams*; and the greater part of it was included by him in this mixed group. The former would include only the limited areas of the Lower Oolites; the latter would include the great clay-tracts and the impersistent band of Corallian limestones, belonging to the Middle and Upper Oolites, with the outlying masses of Portland Beds, the Cretaceous tracts, and the larger areas of Valley drift. Thus grouped a remarkable diversity of soil is encountered, and of land in arable cultivation and pasture, including much good dairy-land and tracts of woodland. In a general description where no attempt can be made to deal in detail with the soils, the above grouping is convenient.

The Stonebrash region commences with the Great Oolite of the country bordering the Evenlode above Hanborough. It there forms the margin of a tract of fairly level upland that descends steeply to the river. Stone-fences divide the fields, and the soil is a brashy or rubbly loam or clay.

Fragments of ironstone were met with in the soil bordering the Alluvium, on the spur east of Ashford Bridge; and it was at first thought likely that the Fawler iron-ore, beneath a thin representative of Upper Lias, might occur there below the Inferior Oolite. Some excavations were made, and these proved that Valley gravel fringed the Oolite at the southern end of this spur. (See p. 10.)

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[1] "View of the Agriculture of Oxfordshire," 1809, p. 3. See also article "On the Farming of Oxfordshire," by Clare Sewell Read, *Journ. Roy. Agric. Soc.*, vol. xv., 1854, p. 189.

The area occupied by Oxford Clay is for the most part gently undulating ground, with here and there a low escarpment, above the Cornbrash, where the sandy strata of the Kellaways Beds are developed. A good deal of the ground is low-lying and almost Alluvial in aspect; the soil is a stiff and heavy clay, except where lightened by thin coverings of gravel or downwashes from the scarps of Lower Calcareous Grit; and the slopes are damp and rushy in places. The hedgerows, as a rule, are well-timbered, with oak and elm, ash, willow, and poplar.

The Corallian Beds yield a variable soil, for the most part light and brashy. Much of it is a rich, friable, sandy loam, generally brown, but sometimes of red colour. The ground is mostly under cultivation for corn and roots, and to some extent as meadow-land, but there are occasional rabbit-warrens on the sandy areas of the Lower Calcareous Grit.

An analysis of soil taken from Little Hill field, Wick Farm, Headington, has been made at Reading College. The soil, which lies on the Calcareous Grit, is described as a light sandy loam, 6 to 9 inches deep, and very free from stones. "The nitrogen and organic matter of this soil are very low, but there is a good supply of phosphoric acid and potash." The subsoil is "free sand, with the rock of the Calcareous Grit in many cases coming near the surface. Although the underlying rock contains lime, the soil is, as a rule, poor in lime, except where the rock comes near the surface."[1]

Near Littlemore the Upper Corallian Beds are very argillaceous, and the soil is comparatively stiff. The grass-lands on the Corallian clays in the area north-east of Wheatley are generally good, modified as the soil is here and there with thin gravelly patches; indeed, the higher tracts of meadow-land near Ickford, Waterperry, and Holton are regarded as among the best grazing and dairy-lands in the western part of the Vale of Aylesbury. The lower-lying ground at Ickford Village, as well as the Alluvial flats, are liable to floods, portions of the village being flooded in 1894, and again in June, 1903.

The Upper Oolites, consisting of the Kimeridge, Portland, and Purbeck divisions, occupy a smaller superficial area than the Corallian, as they are partially concealed by the overlap of Cretaceous strata.

The Kimeridge Clay, overlain directly by Gault, occupies the northern part of the Vale of White Horse, and passes into our region along the Ock Valley at Marcham and Abingdon. Thence it extends to Radley, and rises northwards on the flanks of Boars and Cumnor Hills, where it is cut off by the deep valley of Botley. On the other side of the river it forms the banks below the sands of Nuneham Park, and rising eastward completely encircles the Shotover Hills, passes into the Thame Valley, and spreads out northward to form the base of Brill and Muswell Hills. Noticeable landslips of recent date may be seen along the slopes of Kimeridge Clay, south-west of Wheatley railway-station;

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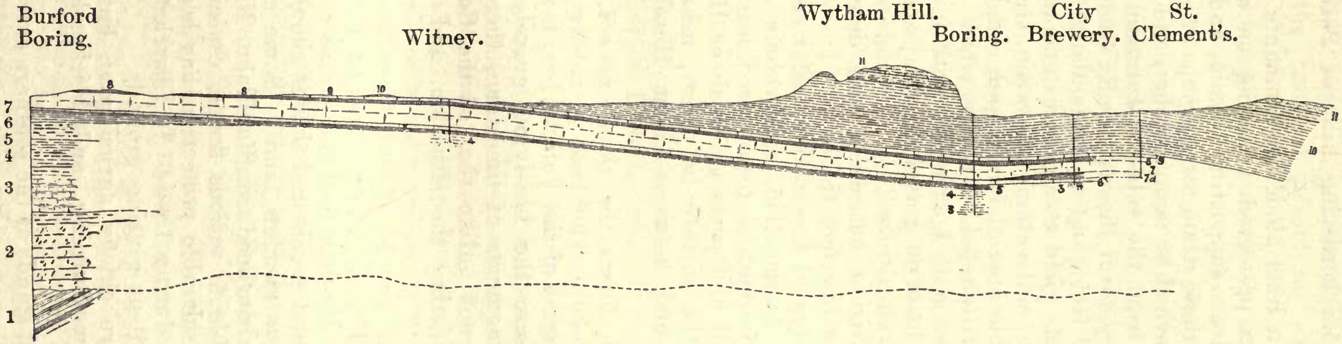
[1] "First Ann. Rep. on the Soils of Dorset, &c.," by D. A. Gilchrist and C. M. Luxmore. 1899, pp. 26, 27, 40.

FIG. 1.—*Section from Burford across Wytham Hill to Oxford.* (*H. B. W.*)

Distance about 18 miles.



4. Middle Lias.
3. Lower Lias.
2. Trias { Rhætic Beds.
{ Keuper Marls.
1. Coal Measures.

7. Great Oolite.
7*a*. Upper Estuarine Beds
6. Inferior Oolite.
5. Upper Lias.

11. Corallian Beds.
10. Oxfordian Beds.
9. Cornbrash.
8. Forest Marble.

and there are evidences of older slips on Shotover Hill and Red Hill. It forms a stiff clay soil that is locally improved by downwashes from bordering hills of Portland Beds and Shotover Sands.

Along the eastern tract alone are remnants of the Portland and Purbeck strata preserved. Resting on a foundation of clay, and themselves supporting sands and clays of the Cretaceous system, these strata form groups of isolated hills and winding ridges trenched by many combes, and thus they stand out in bold relief from the vales of Jurassic clay and Gault around them. They form the outliers of Shotover (516 feet) and Brill (over 600 feet), and the hills about Great Milton.

The Portland Beds yield a calcareous and sandy soil, much of it under arable cultivation. Between Great and Little Milton a considerable area of fairly open country is occupied by these strata. Milton field was described by A. Young as "one of the finest soils I have met with in the county; a dry, sound, friable loam on gravel [rubble]—convertible land, as they call it in Oxfordshire."[1]

The Purbeck division has only been detected in a few places, and is but a few feet thick.

The Shotover Beds and Lower Greensand yield a variety of soils, the texture, composition, and colour alike differing. The higher beds of ironsand form a red ferruginous earthy soil, as on Red Hill and parts of Shotover Hill. Loamy or clayey beds form the surface in places, near the windmill at Great Milton, and between Great Haseley and Little Haseley.

The Gault which forms the slopes near Latchford, gives rise to a stiff clay-soil. The land is mostly under grass.

On the Alluvial areas of the Vale of Isis, between Eynsham and Standlake, where the low-lying gravels are composed largely of rolled fragments of limestone, there is a reddish-brown brashy soil not unlike that of the Cornbrash. This is fairly dry considering the situation, and furnishes good corn-land.

An analysis of a sample of soil from Stanton Harcourt made in 1870 by Dr. A. Voelcker, showed 32 per cent. of carbonate of lime. He described the soil as a clay-marl with a gravelly subsoil, and considered that it should "be used as arable rather than as meadow land." Some of the gravelly tracts in this neighbourhood, at Standlake, Northmoor, and Eynsham, were liable to serious floods, especially from the Windrush, but considerable protection has been afforded by embankments made during 1866-67.[2] Elsewhere the Alluvial meadows form excellent grazing grounds.

The industries are chiefly agricultural, but they include stone-quarrying, lime-burning, and brickmaking for local purposes.

The city of Oxford stands at the southern extremity of a long insulated tract mostly of Oxford Clay, capped by gravel, and surrounded by Alluvium. This tract extends from Kidlington on the north to the confluence of the Thames and Cherwell, above which is the bank of gravel on which the city is placed.

---

[1] "Agriculture of Oxfordshire," 1809, p. 8.

[2] S. B. L. Druce, *Journ. Roy. Agric. Soc.*, ser. 2, vol. vi., 1870, p. 373.

Of the history of the occupation of the site we learn from Mr. James Parker that there is no evidence of any settlement of importance in British times, and the site was not traversed by any of the old Roman ways; that the founding of a nunnery by St. Frideswide about the year 727 "upon the spot now occupied by Christ Church," is legendary, although not improbable; but that nothing about Oxford is known with certainty prior to "A.D. 912, when King Edward the Elder took possession of the place."

The name then recorded of *Oxnaforda* is the earliest form of spelling, and "distinctly represents 'the ford of the Oxen'"; but it has been held "that the name is a corruption of Ouse-ford or Ousen-ford," that is, "the ford over the *river*." On this subject authorities are not agreed.

"The earliest foundation provided for scholastic purposes in Oxford" dates from 1249, and is represented by University College;[1] but Merton College claims to have been the first to establish the college system in 1274.[2] From that date, at any rate, the city became a seat of learning; and in due course geology found a place in the curriculum.

John Phillips[3] has recorded that "the Museums of the University of Oxford contain the oldest public collection ever formed in the British Isles for the illustration of natural history, antiquities, and archæology." The Ashmolean Museum, when completed in 1683, was placed in charge of Robert Plot, and afterwards of Edward Lhwyd, to both of whom we are indebted for early knowledge of the fossil organic remains of the neighbourhood of Oxford.

About a century later, systematic investigation of the strata was commenced by William Smith, who published geological maps of the three counties, portions of which are included in our district.

The study of geology was first taught by Dr. John Kidd, the Professor of Chemistry, who may be said to have inspired W. D. Conybeare, William Buckland, and others. To them, to Fitton, John Phillips, Dr. J. F. Whiteaves, J. F. Blake, Mr. W. H. Hudleston, Mr. James Parker, and to the more recent observations of Mr. A. Morley Davies, our knowledge of the local geology, apart from the work of the earlier Geological Survey, is largely due.[4]

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[1] James Parker, "The Early History of Oxford," 1885, pp. 2, 53, 63, 348, 351.

[2] "Memorials of Merton College," by the Hon. G. C. Brodrick, 1885, p. 6.

[3] See Phillips, "Geology of Oxford," &c., 1871, p. 1; and W. J. Sollas, "The Influence of Oxford on the History of Geology," *Science Progress*, viii., 1898, p. 23, reprinted in "The Age of the Earth and other Geological Studies," 1905, p. 219.

[4] See the Director's Preface and the Appendix.

CHAPTER II.

LOWER OOLITIC ROCKS.

BY T. I. POCOCK.

Along the banks of the Evenlode, above the point where it enters the Oxford plain, the oldest rocks in the neighbourhood come to the surface. They rise with gentle inclination from beneath the Oxford Clay in nearly the same direction as the valley, but at a slightly greater angle, so that as they are traced up-stream successively lower strata are brought up. Though much reduced in thickness, and wanting several of the subdivisions, the Lower Oolitic series is the same as that which, further west, forms the fine escarpment of the Cotteswold Hills.

The main divisions represented in the area are as follows:—

Great Oolite Series	Cornbrash. Forest Marble. Great Oolite. Upper Estuarine Series.
Inferior Oolite.	

INFERIOR OOLITE.

Only the upper portion of the Inferior Oolite is present, viz. the zone of *Parkinsonia Parkinsoni*, the lower zones being overlapped in succession as the formation is followed eastward from the Cotteswold escarpment.[1] Unfortunately no good sections are exposed within the limits of the map.

The sections on the scarp near Stonesfield Ford, to the north of the area, showed the two upper subdivisions of the Inferior Oolite:—

Chipping Norton Limestone—Hard, fine-grained oolitic limestone.
Clypeus Grit—Rubbly oolitic and pisolitic limestone, with *Clypeus Ploti, Pholadomya, Trigonia, Pleuromya,* and *Rhynchonella.*

The outcrops within the map are on either side of the river by Ashford Mill, that on the right bank being brought up by a fault running southward to Holly Court Farm, that on the left by a sharp upfold or a fault. The latter was proved by digging a small pit in the field next the railway, which showed ironshot oolite of the Clypeus Grit division one foot below the surface. There was also some indication in the surface soil of the buff limestone, known as the Chipping Norton Limestone. Probably the whole series crops out low down on the valley slopes, the bed of the river being upon Lias, for at Fawler the maximum thickness is 37 feet, and it is most likely less here.

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[1] E. Hull, *Quart. Journ. Geol. Soc.*, xvi., p. 72; and H. B. Woodward, "Jurassic Rocks of Britain," iv., p. 150.

At Fawler, a little to the north-west of our district, the section is given as follows by Mr. Woodward[1]:—

			Ft.	in.
Inferior Oolite.	Chipping Norton Limestone.	Oolitic limestone of variable texture, with occasional marly layers. Few fossils occur; but *Pholadomya* and Echinoids may be found 12 0 to	15	0
	Clypeus Grit.	Rubbly oolitic marls and coarse marly oolites, with *Clypeus Ploti*, *Parkinsonia Parkinsoni*, *Pholodomya Dewalquei*, *Terebratula globata*, &c. 8 0 to	12	0
	Lower Beds of Ragstone.	Marly limestones ... ... 5 0 to	6	0
		Coarse oolitic, and almost pisolitic, limestones, with *Gervillia*, *Isocardia*, *Lima gibbosa*, *Modiola Lonsdalei*, *Pleuromya*, *Pecten vagans*, *Rhynchonella concinna*, *R. obsoleta*, *R. varians*, *Serpula*, &c.	4	0
		Hard iron-shot limestone, with pebbly layer at base; Corals, *Echinobrissus clunicularis*, *Rhynchonella spinosa*, *Terebratula globata*, and *T. maxillata* (smooth form)		

Upper Lias—Blue Clay.

From the basement-bed (above the Upper Lias Clay) Mr. E. A. Walford obtained small blocks of limestone covered with *Plicatulæ* and pierced with *Lithodomi*; and he recorded the occurrence of *Trigonia producta*, *T. angulata*, &c.

The section indicates that the upper beds of the Inferior Oolite overlap the lower beds and rest directly on the Upper Lias, as is also the case near Burford.

The Chipping Norton Limestone, described under this name in 1878 by Mr. W. H. Hudleston,[2] forms the highest part of the Inferior Oolite in this district. Nevertheless, as pointed out by Mr. Walford and others, the fossils recorded from it present Bathonian characters. The superincumbent deposits are variable, and comprise clays and marls with *Ostrea acuminata* J. Sow., *O. Sowerbyi* M. & L., *Nerinæa Eudesi* M. & L., &c., and representatives of the Stonesfield Slate. These strata may be looked upon as more or less equivalent to the Fuller's Earth (Fullonian) formation on the one hand, and the Upper Estuarine Series on the other.

GREAT OOLITE SERIES.

UPPER ESTUARINE SERIES.

In the deep boring at the City Brewery, Oxford, beds of grey and black clay with iron-pyrites, "beef," lignite, &c., were encountered below the Great Oolite at a depth of 377 feet 8 inches, and proved to a thickness of 28½ feet. They were grouped by the late J. H. Blake (in conference with H. B. Woodward) with the Upper Estuarine Series.

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[1] "Jurassic Rocks of Britain," iv., p. 154. See also *Proc. Geol. Assoc.*, iv., p. 95; Hull, *Geologist*, iii., p. 304; Hull, "Geol. Woodstock," p. 15; Walford, *Quart. Journ. Geol. Soc.*, xli., p. 39; F. A. Bather, *Ibid.*, xlii., p. 144.

[2] *Proc. Geol. Assoc.*, v., p. 384. See "Jurassic Rocks of Britain," iv., p. 151.

Particulars of these strata and of the fossils met with are given in the record of the boring (p. 124). Among the fossils were *Cyrena?*, *Placunopsis socialis?* M. & L., *Ostrea Sowerbyi* M. & L., *Mytilus* sp., *Hinnites* sp., and *Rhynchonella subtetrahedra* Dav.

No outcrop of these strata has been observed in the region of the Oxford map, although they probably occur at the base of the Great Oolite in the north-western portion of the area. They are the clays previously referred to as overlying the Chipping Norton Limestone; and they have since been proved to occur beneath the Stonesfield Slate at Stonesfield by Mr. E. A. Walford, where, curiously enough, the thickness was exactly the same as that in the Oxford well, 28½ feet.[1] From the occurrence in the clays of *Neæra*, Mr. Walford designates them as the "Neæran Beds."

GREAT OOLITE, FOREST MARBLE, AND CORNBRASH.

The Great Oolite, together with the Forest Marble and Cornbrash, form the bluffs of the Evenlode between Hanborough Railway Station and Ashford Mill, and pass westward by a cross valley near Wilcote, to the Windrush. This will be referred to as the Wilcote Valley. A small area of the Cornbrash in a tributary valley of the Windrush near Witney is also included in the map. East of Hanborough the series extends by Bladon to Kidlington, where it passes northward outside our region. At Islip is a large inlier within the Oxford Clay area which shows all three divisions of the group. A smaller inlier on the north bank of the River Ray by Oddington extends to Charlton beyond the margin of the map.

The divisions now to be considered are as follows:—

	Feet.
Cornbrash—Zone of Macrocephalites macrocephalus, *Schloth*, tough shelly limestone in layers, without false-bedding or oolitic structure	9 to 17
Forest Marble—Flaggy and shelly oolitic limestones, current-bedded and alternating with thick beds of clay and layers of gritty limestone	15 to 35
Great Oolite (Upper)—White limestones with marls, evenly bedded, and with scattered oolitic grains	Up to 60
Great Oolite (Lower)—False-bedded oolitic freestone, shelly limestones, clays and sandy flags (Stonesfield Slate) ...	Up to 40

Considerable difficulty is found in many places, as Mr. Woodward points out, in making any but conventional divisions between the Lower and Upper Great Oolite, and between the Great Oolite and Forest Marble. It seems best, therefore, not to separate our descriptions of these formations, nor of the Cornbrash, which is also exposed in many of the pits.

Witney.

Near Witney the thickness of the Forest Marble, about 34 feet, is more than twice as great as it is at Hanborough, and the formation consists of false-bedded limestones covered by a bed of clay, which is persistent for several miles.

Occasional small exposures of the Cornbrash may be seen by following the brook north-eastwards from Newland. The rock here, as in many other places, covers a wide area, the overlying Oxford Clay having been denuded without any considerable destruction of the resistent beds below, so that the dip of the strata coincides almost exactly with the surface-slope.

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[1] *Rep. Brit. Assoc.* for 1895, p. 415; "On some New Oolitic Strata in North Oxfordshire," 4to, Buckingham 1906, p. 18.

Wilcote Valley.

In the Wilcote Valley the dip of the beds is slightly east of south, so that the outcrop of Forest Marble is much broader on the northern slope than on the southern. The relation of the white limestone of the Great Oolite with overlying Forest Marble may be seen in an old quarry a quarter of a mile west of Wilcote.

Another section at the southern end of Holly Grove Plantation, Wilcote, showed only the hard, shelly, false-bedded oolite with clay-partings, belonging to the Forest Marble. Near North Leigh and New Yatt the Cornbrash has been mostly concealed by the wash from the drift-beds at the top of the hill, and perhaps partially dissolved away at its outcrop by weathering.

East of Bridewell Farm the white limestone of the Great Oolite was formely quarried for lime-burning. A section may also be seen south-east of Fisher's Gate, a quarter of a mile north-east of North Leigh Church :—

		Ft.	in.
Great Oolite	Soil and rubble	3	6
	Thin-bedded white limestone	5	0
	Clay	0	6

The limestone, which was said to be in thicker beds below, has been quarried for building-purposes, but is now only used for lime-burning. From this quarry the following fossils were obtained :—*Cyprina* ?, *Trigonia*, sp.; *Nerinœa*, sp.; *Mesodon*, sp.[1] An interesting section should be examined near Holly Court Farm, high up on the right bank of the brook. The flaggy oolites of the Forest Marble are there seen resting on the white limestone of the Great Oolite. Between the two is a thin bed containing fragments of the underlying limestone, and affording evidence of local erosion.

Evenlode Valley.

Below Ashford Mill practically the whole of the Great Oolite group is included in a bluff on the right bank of the River Evenlode. The thickness may be estimated at about 130 feet. The Lower Division is not exposed, but a quarry showing part of the Upper Division, and the Forest Marble, may be seen a quarter of a mile south-east of the Mill, by the road-side. The succession of beds is given by Mr. H. B. Woodward as follows :—

Section in a quarry by Whitehill Wood, north of North Leigh (the uppermost beds were not accessible) :—

		Ft.	in.
Forest Marble	Rubble.		
	Dark clay.		
Great Oolite (Upper Division)	Greenish and white rubbly marl.		
	Pale earthy limestone.		
	Grey marly clay	4	0
	Hard pale earthy limestone	1	3
	Sandy marl, with bands of earthy and shelly limestone	5	0
	Oolitic limestone	2	0
	Blue and brown clay	0	4
	Hard brown oolitic and shelly stone ...	0	3
	Oolite	3	0
	Greenish marl	2	0
	Hard brown oolitic stone	1	0
	White and pinkish shelly and oolitic limestones	8	0

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[1] These were named in the Palæontological Department.

This section includes higher beds than those at Ashford Bridge, and they evidently belong to the series of white limestones and marly beds above the freestone of Taynton: such as may be seen at Milton, near Shipton-under-Wychwood, some miles west of the area. The mass of the Great Oolite between Milton and Woodstock appears to be of variable character, and the Lower Division is probably much attenuated.[1] H. B. W.

On the left bank of the Evenlode there is a quarry showing the junction of the Lower Division of the Great Oolite with the Upper Division. This quarry is close to Westfield Farm on the eastern side of the river, north of the railway and north-east of the Roman Villa of East End. The section shows false-bedded shelly white oolite with a thin band of marl in the upper part. The following fossils were obtained[2] :—

From the strata above the marl band.

Astarte ? Trapezium sp. Nerinæa ?

From the marl band.

Acrosalenia cf. Wiltoni *Wright*
Clypeus sp.
Echinobrissus cf. Woodwardi *(Wright)*.
Terebratula maxillata *J. de C. Sow.*
Astarte ?
Cyprina cf. nuciformis *Lyc.*
Homomya ?
Lima (Limatula) gibbosa ? *(J. Sow.)*.
Lucina rotundata ? *(F. A. Roemer)*.
Pholadomya heraulti ? *Ag.*
Pleuromya ?
Tancredia ?
Trapezium nuculiformis ? *(F. A. Roemer)*.
Chemnitzia ?
Natica sp.
Trochus ?

From the strata below the marl band.

Echinodermal remains.
Terebratula sp.
Lima sp.
Ostrea (fragment).
Pecten sp.
Pinna cf. cuneata *Phill.*
Pleuromya calceiformis (*Phill.*).
Trigonia ?

The Great Western Railway (Worcester branch) is carried along the valley by means of deep cuttings through the projecting spurs between the bends of the Evenlode. These cuttings, though much concealed, still show good sections of the Upper Division of the Great Oolite.

Mr. Woodward remarks that the beds seen in the cutting near Ashford Bridge, north of the Mill, and just beyond the limits of the map, were as follows :—

		Ft.	in.
Great Oolite.	Rubble of oolite, marl, &c.		
	Fissile and false-bedded oolites and marls ... ... Oolitic limestone, with corals ...	15	0
	Marly and carbonaceous oolite ... Clay and sandy shales, with *Ostrea Sowerbyi*	5	0
	Pale-grey limestone with *Nerinæa Eudesi*, *Astarte angulata*, &c.	1	0
	Fissile and shelly oolite, with *Nerinæa* at top	6 to 8	0

The section has been described by John Phillips and others[3] ; as well as by R. F. Tomes[4] who obtained from the Coral-bed, *Astrocœnia Phillipsi*, *Cryptocœnia Pratti*, *Isastræa gibbosa*, *I. limitata*, *Montlivaltia*, *Thamnastræa Lyelli*, &c. He also obtained *Cyathophora Bourgueti* from the bed above the *Nerinæa*-limestone. A number of Gasteropods and other fossils were obtained, by T. J. Slatter, from the Great Oolite in this cutting: they include *Fibula variata*, *F. eulimoides*, *Natica Michelini*, *Neridomus minutus*, *Ataphrus discoideus*, *Delphinula alta*, and *Solarium varicosum*. Many other fossils, together with *Cypricardia nuculiformis*, and *C. rostrata*, have been recorded by Dr. J. F. Whiteaves. The lowest bed of oolite may perhaps represent the Taynton freestone, for as remarked by Tomes, all the beds "overlie the Stonesfield Slate, which is under the line of railway."—H.B.W.

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[1] "Memoir on Jurassic Rocks of Britain," iv., p. 318 ; see also Green, Geol. Banbury, p. 23.

[2] The specimens obtained during the recent Survey, have been named in the Palæontological Department.

[3] Phillips, *Quart. Journ. Geol. Soc.*, xvi., p. 116 ; A. Gaudry, *Bull. Soc. Géol. France*, ser. 2, tome x., p. 594 ; J. F. Whiteaves, *Rep. Brit. Assoc.* for 1860, p. 105.

[4] Tomes, *Quart. Journ. Geol. Soc.*, xxxix., p. 171.

The Stonesfield Slate does not appear in the area, but full particulars of the strata, the method of working, and lists of fossils have been elsewhere given.[1]

At East End, north-east of North Leigh, are several quarries near together, which show the white limestone of the Great Oolite, the Forest Marble and the Cornbrash.

It may be noticed that the Cornbrash, though so thin, here spreads out into a plateau half a mile long, similar to the broad outcrop of the same formation near Witney.

At Combe Cliff, north of the railway and of Mill Wood, Long Hanborough, the strata are of the same character. The lower division of the Great Oolite is for the most part below the level of the river, but a considerable portion of the higher strata, comprising about 70 ft., is visible in the railway-cutting north-west of Mill Wood, and in the following quarry sections:—

Quarry east of Grintleyhill Bridge, about ¼ mile N.W. of Mill Wood.

		Ft.
Great Oolite	Thin-bedded shelly oolite	8
	Pale marl	1
	Thick white oolitic limestone	2
	Marly limestone	3
	Thick-bedded shelly limestone ...	3

A quarry in the wood above Combe Cliff near the east side, north of the road, showed:—

		Ft.
Cornbrash ...	.. ..	3
Forest Marble	Marl	1½
	False-bedded limestone with clay beds ...	10

Along Combe Cliff, on the south side of the road, the white limestone of the Great Oolite is exposed. On the opposite side of the river the several divisions are again exposed in two quarries by the road leading northwards from Long Hanborough towards East End, Combe. The disused quarry south-west of the bridge over the Evenlode, is in the white limestone of the Great Oolite; that known as Hanborough Quarry, north of the Swan Inn, showed the following section:—

		Ft.
Oolitic gravel	... ...	2 to 3
Cornbrash ...	... ...	9
Forest Marble	Greenish-grey clay	4
	False-bedded limestone	4

Here may be noticed a considerable reduction in the thickness of the Forest Marble limestones. According to the information of the proprietor they disappear altogether in the field on the opposite side of the road.

From this quarry, in 1904, we obtained two Ammonites, presumably from the Cornbrash, but not *in situ*. They were seen by Professor J. F. Blake, who named them *Clydoniceras hochstetteri* (Oppel), and *Perisphinctes subbakeriœ* (d'Orb.).

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[1] H. B. Woodward, "Lower Oolitic Rocks of England," vol. iv. of "Jurassic Rocks of Britain," 1894, pp. 310–317 484, 485.

The following fossils were obtained from the Forest Marble[1] :—

Pentacrinus (columnals).
Cidaris sp.
Echinoid remains (spines and plate fragments).
Serpula sp.
Diastopora diluviana ? *Edw.*
Microthyris obovata ? (*J. Sow.*).
Rhynchonella cf. concinna (*J. Sow.*).
———obsoleta ? (*J. Sow.*).
Terebratula intermedia? *J. Sow.*
Ostrea Sowerbyi ? *M. & L.*
———subrugulosa ? *M. & L.*
Pecten (Camptonectes) lens *J. Sow.*
———cf. personatus *Goldf.*
Placunopsis socialis *M. & L.*
Dentalium sp.
Monodonta cf. tegulata *Lyc.*
Fish-remains.

The change noticed in the Forest Marble at Long Hanborough quarry is still more marked in the railway-cutting by the station. The Cornbrash can be seen at the top all the way, coming to the level of the rails at the end nearest Oxford. At the opposite end the Forest Marble division consists of about 14 feet of clay with a thin stone-band in its upper part, and, underneath, the white limestone of the Great Oolite can be followed for about 500 yards towards the road-bridge, where it dips below the rails. The base of the Forest Marble is marked by a detrital bed containing fragments of the white limestone, as was observed near North Leigh. But near the bridge thick beds of oolitic limestone come in seven feet below the Cornbrash. They are at a higher horizon than the white limestone further west, and seem to belong to the Forest Marble. In appearance, however, they are more like some beds of Great Oolite.

Very similar beds are seen in the quarry at the corner of the roads north-east of Hanborough Station ; they are as follows : —

		Ft.
Cornbrash	Rubble	1
	Hard shelly limestone	3
Forest Marble	Grey clay with "race"	4
	Compact brown limestone ... False-bedded and fissile oolite, with thin partings of clay, and layers of hard shelly and blue-hearted limestone in places. Fish-remains (palatal teeth)	12

The grouping here adopted differs from that given by Mr. Woodward who remarked that the lower beds appear to correspond with those referred to the Great Oolite in the quarry north-east of Bladon[2]. They are, however, just like the strata that occur above the white limestone of the Great Oolite in the railway-cutting to the north-west.

The following fossils were obtained :—

From the Cornbrash.

Terebratula intermedia *J. Sow.*
Microthyris obovata ? (*J. Sow.*).
Lima sp.
Pleuromya sp.

From the strata below.

Clypeus.
Serpula intestinalis *Phill.*
Diastopora ?
Rhynchonella concinna ? (*J. Sow.*).
Astarte ?
Modiola sp.
Ostrea sp.
Placunopsis socialis *M. & L.*

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[1] These have been named in the Palæontological Department of the Geological Survey.

[2] "Jurassic Rocks of Britain," iv., p. 319.

Similar beds of Cornbrash and false-bedded limestone may be seen in an old quarry on the opposite side of the river near the bridge. The false-bedded limestones shown in these sections can be followed southward in a series of quarries near the road as far as the Mill, where the Cornbrash comes down to the river-bank and can be seen under the gravel terrace. By Pinsley Wood a slight upfold appears to bring the Forest Marble again to the surface, though it is not exposed in section. The Cornbrash, however, is seen in old quarries at the southern corner of the wood, and at Goose Eye Cottages by the river side. In a deep brook-bed west of Church Hanborough, Cornbrash is exposed for a distance of half a mile between banks of Oxford Clay.

Below Hanborough the steep bluffs which are characteristic of the river-course through the Lower Oolite rocks, gradually disappear, and the valley broadens out on the plain of the Oxford Clay. The white limestone extends to the mouth of the Glyme by Bladon. Two miles to the south the top beds of the Great Oolite Series are finally lost at the foot of the slope by Purwell Farm.

Glyme Valley.

The following notes are by Mr. H. B. Woodward[1]:—

A quarry north-east of Bladon showed the following section :—

		Ft.	in.
Soil	Brown brashy loam	2	0
Cornbrash	Hard brown and grey rubbly limestones, with *Terebratula intermedia* *Sow.*	4	0
Forest Marble	Blue and brown clay, with thin bands of shelly and oolitic limestone	3	6
	False-bedded brown oolitic limestones with *Rhynchonella*	2	0
	Blue clay (of irregular thickness), with lignite and compressed shells	0	8
	Blue and grey marly oolitic limestone (of irregular thickness)	0	10
	Dark blue and grey clay	1	6
	Buff and blue false-bedded oolite. Bottom beds used for building	3	6
	Thin clay (impersistent).		
Great Oolite	Buff and blue oolitic and shelly limestones without clay-partings. (Building-stone.) Fish-remains ... about	10	0

["Soft limestone, not worked."]

The above grouping corresponds with that adopted by Professor Hull.[2] Although just beyond the confines of the map, the succession recorded in the railway-cuttings on the branch railway to Woodstock will be useful for comparison :—

		Ft.	in.
Kellaways Beds	Fine yellow and grey sands	5	0
	Dark bluish-grey, and stiff mottled brown clay, with "race," and much ferruginous matter at the base	10	0
	Thin layer of sand overlying seam of clay	0	5

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[1] "Jurassic Rocks of Britain," iv., 1894, pp. 373, 446—448.

[2] Geol. Woodstock, p. 23 ; see also Green, Geol. Banbury, p. 25.

		Ft.	in.
Cornbrash	Rubbly and fissile marly limestone, with lignite: *Waldheimia lagenalis* (Schloth.), large *Ostrea*	1	0
	Impure limestones with lignite and pyrites: *Rhynchonella varians* (Schloth.)	1	2
	Hard mottled limestones: *Modiola*, *Pecten lens* Sow., *Trigonia*, *Waldheimia lagenalis*, *W. ornithocephala* (Sow.)	1	6
	Soft earthy and shelly marl and mottled blue and grey limestone: *Astarte elegans* Sow., *Avicula echinata* Sow., *Isocardia*, *Homomya Vezelayi* (Laj.), *Pleuromya*, *Ostrea*, *Pecten vagans* Sow., *Pholadomya Phillipsi* Mor., *Trigonia*, *Microthyris obovata* (Sow.), &c.	4	0
	Hard bluish-grey limestones with marly patches: *Avicula echinata*, *Gresslya*, *Pleuromya*, *Pecten vagans*, *Trigonia*, *Echinobrissus clunicularis* (Lhwyd)	2	0
	Fissile marly beds and tough brown and grey shelly limestone, with *Avicula echinata*, and *Terebratula intermedia* (very abundant)... ...	2	0
Forest Marble	Blue and greenish-grey clay with nodules of limestone...	6	0
	Shelly oolitic and marly limestone, false-bedded ... ... 1 ft. to	2	6
	Blue and grey shaly clay and marly oolitic beds, with irregular layers of blue flaggy and false-bedded oolitic limestone	11	0
Great Oolite (Upper Division)	Oolites, presenting a somewhat mottled appearance (like some beds of Cornbrash), with pale-grey, blue, and greenish tinges, due to irregular staining and weathering: *Nerinœa* (abundant), *Ostrea* and Corals ... ... 1 ft. 6 in. to	2	0
	Limestone ... ...1 ft. to	1	6
	Shelly limestone, with *Astarte*, *Gervillia*, and some Gasteropods ...	1	0
	Pale grey earthy limestone (blue-hearted)	4	0
	Compact limestones with scattered grains of oolite		
	Green and grey racy clay, passing down into black carbonaceous and racy clay with much lignite 3 ft. 6 in. to	6	0
	Earthy oolitic limestone, with *Cyprina*, *Ostrea Sowerbyi*; and gritty oolitic clay	5	0
	Clay, *Ostrea* abundant...	1	8
	Slightly oolitic limestone, compact and shelly ... ... 1 ft. 8 in. to	2	0
	Oolitic limestones ... ...4 ft. to	4	6
	Fossil bed: marly limestone, occasionally oolitic, with *Terebratula maxillata* very abundant (all sizes and conditions), *Lima cardiiformis*, &c. 3 ft. to	4	0

The fossil-bed at the base merges irregularly into the bed above. The green and black clay recalls beds of Great Oolite Clay in the country to the north-east. It is difficult to correlate the strata with those of the Bladon Quarry; indeed the limestones of the Great Oolite vary much in character, and there appear to be evidences of overlap and reconstruction at the base of the Forest Marble, suggesting local unconformity. (See also pp. 13,16.)

The thickness of the Cornbrash was from 12 to 14 ft. Its basement-bed, crowded with fine specimens of *Terebratula intermedia*, was a noticeable feature; and it was interesting to compare these forms with the allied and even more abundant specimens of *T. maxillata* found in the Great Oolite below. The limestones of the Cornbrash, as seen in this railway-cutting, were variable in character and induration; where under the Kellaways Clay the rock was usually a hard dark blue or bluish-grey stone, much of it having a mottled appearance, not unlike some beds of Great Oolite. The mottled layers are caused by irregular admixture of marly matter.[1] H. B. W.

The white limestones of the Great Oolite were well exposed in the old quarry at Hensington, by Bladon.

In Blenheim Park the boundaries drawn between Forest Marble and Great Oolite, north of the Glyme, are conjectural owing to lack of evidence. A section north of the new bridge below the lake showed the following beds:—

		Ft.
Forest Marble	Flaggy limestone	3
Great Oolite	White marl	3
	Hard white oolitic limestone	2
	Fine-grained oolite	

On the drive between the High Lodge and Lince Lodge there are occasional openings in the Forest Marble; one near High Lodge showed the Cornbrash as well; and another, a quarter of a mile N.W. of Lince Lodge, showed the underlying White Limestone. These sections exhibit the flaggy and highly oolitic limestones characteristic of the Forest Marble, and their general persistence in this region, though they appear to thin away locally at Long Hanborough.

Cherwell Valley.

To the east of Bladon the Cornbrash spreads in a broad slightly inclined plane to the Cherwell. The Forest Marble crops out along the brooks north of Begbroke, and again west of Kidlington, but no lower beds come to the surface. These strata dip under the Oxford Clay between the two villages, and are not seen again towards the south.

At Campsfield Farm, one-third of a mile north-west of Kidlington Station, the following quarry section was to be seen:—

	Ft.
Cornbrash	9
Forest Marble—False-bedded limestone with thin clays	20

In the adjacent railway-cutting the same two divisions have been exposed, the Cornbrash extending from the top at the north end downwards towards the station, where it is concealed by river gravel.

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[1] "Memoir on the Jurassic Rocks of Britain,' iv., pp. 321, 373 and 447.

Half a mile due east of the railway-cutting, in an old quarry, Mr. H. B. Woodward recorded the following section, which is now partially concealed by slipping[1]:—

		Ft.	in.
Cornbrash	Rubbly limestone, with *Avicula echinata* (abundant)	4	0
	Grey racy clay	0	8
	Rubbly limestone: with fine examples of *Microthyris obovata* in upper portion, and *Terebratula intermedia* in lower part	3	0
Forest Marble	Blue-hearted gritty limestone	0	6
	Laminated calcareous sands and clays ...	1	0
	Fissile shelly and oolitic limestone: false-bedded. Seen to depth of	3	0

A large collection of Cornbrash fossils, including about 76 species, was made in this neighbourhood by Dr. J. F. Whiteaves.[2] The Ammonite *Clydoniceras discus* (J. Sow.), has been recorded from Kidlington.[3]

Within a short distance of the sections above described the Lower Oolitic rocks disappear under the flood-plain of the Cherwell.

Ray Valley.

Along the northern margin of Ot Moor there is a remarkable series of inliers of the Great Oolite Series that protrude in isolated ridges surrounded by low alluvial tracts, over which wander the almost stagnant waters of the Ray and its tributaries.

These inliers are situated along a line of upheaval, approximately parallel to the general strike of the formations of the region taken as a whole. But there are minor disturbances in a direction at right angles to this, which cause undulations in the strata of smaller amplitude and wave-length. The structure is further complicated by faults, which in one case have displaced all the strata up to the Shotover Sands along a line extending from Islip across the Thame Valley, 12 miles away. The line of upheaval extends north-eastward into Buckinghamshire far beyond the limits of the map. In the opposite direction it may be clearly traced in the structure of Wytham Hill, though the disturbance is much less intense; but further on it appears to die out, for no Lower Oolites are brought up within the main outcrop of the Oxford Clay towards the south-west until we reach the neighbourhood of Trowbridge in Wiltshire.

The largest and most disturbed of the inliers is approximately bell-shaped, the length from north-west to south-east being rather over two miles, and the breadth somewhat less. It supports the villages of Islip, Noke, and Woodeaton. The general structure is an anticlinal dome dislocated by faults, but the complication of detail is too great to be determined with exactitude by such field-evidence as was available. The

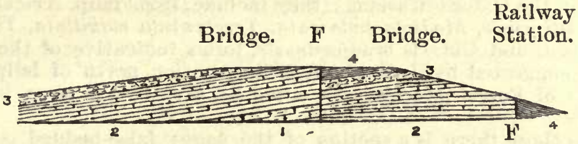
[1] "Jurassic Rocks of Britain," iv., p. 448.

[2] *Rep. Brit. Assoc.* for 1860, p. 107. See also Hull, Geol. Woodstock, p. 25; and Phillips, Geol. Oxford, p. 238.

[3] J. F. Blake, "Monograph of the Fauna of the Cornbrash," *Pal. Soc.* 1905, p. 54.

railway-cutting, of which a diagram is here given (see Fig. 2), though much overgrown, shows all the strata involved in the anticline.

FIG. 2.—*Section of Islip Railway-cutting.*



4. Oxford Clay.
3. Cornbrash.
F. Faults.
2. Forest Marble.
1. Great Oolite.
Length of section, 600 yards.

On the west, south, and east sides of the inlier the Cornbrash is seen to dip normally towards the clay tract beyond. North of Islip, however, the beds appear to strike towards the Oxford Clay, as if the inlier were bounded by a fault in that direction. At the summit of Noke Hill and at Islip the Forest Marble emerges in irregular outcrops, faulted for a considerable distance on the east side against Oxford Clay. The White Limestone of the Great Oolite crops out on the west slope of Noke Hill, where it appears to dip normally under the Forest Marble towards the River Cherwell, but on the other side the junction is probably a fault, though there are no sections to prove this.

The two divisions are shown in a quarry at the cross-roads on the top of the hill between Noke and Woodeaton. The strata are nearly horizontal:—

		Ft.	in.
Forest Marble	Flaggy limestone	6	0
	Clay, with *Ostrea*	0	6
Great Oolite	...White limestone.		

Between this quarry and Islip the Forest Marble was formerly worked for road-metal, but there is now only one pit open about 200 yards south of the bridge over the Ray. It showed the following strata :—

		Ft.	in.
Soil and Cornbrash		2	6
Forest Marble	Blue clay	1	0
	White marl	1	0
	Oolitic brash ("pendle")	1	0
	Marly limestone with corals, *Ostrea*, *Lima*, and large *Pecten*.		

At Islip quarry, one-third of a mile S.W. of the railway-station, close to the cutting, is the following section described by Mr. H. B. Woodward:—

		Ft.	in.
Cornbrash	Rubbly limestone with *Waldheimia* (now *Microthyris*) *obovata*, *Homomya*, &c. ...	5	0
Forest Marble and Bradford Clay	Grey clay with thin bands of limestone (impersistent)	1	2
	Fissile layers of brown sandy and false-bedded limestone, ripple-marked ; with clay-bands	1	0
	Blue and grey laminated clay	1	7
	Hard grey marl with dark oolitic grains and many fossils (impersistent)	0	6
	Grey marly clay	0	6
Great Oolite	Blue and yellow oolitic limestone, much false-bedded	5	0

The fossil-bed yielded much lignite, also *Lima cardiiformis*, *Ostrea Sowerbyi*, *Pecten lens*, *P. vagans*, *Waldheimia cardium*, *W. digona*, *Rhynchonella concinna*, *Serpula*, Polyzoa, and spines of Echini.

Numerous fossils were collected many years ago by Dr. J. F. Whiteaves from the Forest Marble at Islip and Kidlington.[1] Many of the specimens are now in the Oxford Museum; they include, from Islip, *Avicula costata*, *Corbula islipensis*, *Modiola imbricata*, *Terebratula maxillata*, *Terebellaria ramosissima*, and *Cidaris bradfordensis*, forms indicative of the Bradford Clay, as suggested by Lycett. Another section north of Islip, showing about 5 ft. of Forest Marble, was noted by Mr. W. Whitaker, but is now covered.[2]

Besides these there is a section of the flaggy false-bedded oolites in a quarry at the Home Farm, Woodeaton, and the Cornbrash is well exposed by a barn a quarter of a mile to the south-west.

The marked dip of the strata to the south shows clearly the structure of the hill on this side. At the quarry east of Noke village the Cornbrash dips to the north-east. Between here and the Ray it is bent up into a subsidiary dome about half a mile in diameter, separated by a depression from Noke Hill, which probably marks the continuation of one of the faults in the Islip railway-cutting.

On the other side of the river the villages of Oddington and Charlton stand on separate domes of Lower Oolite, each a mile long and a quarter of a mile broad, raised about 20 feet above the Alluvium of Ot Moor. The Cornbrash occupies the greater part of the surface, but the Forest Marble comes up in the middle, at the crests of the domes.

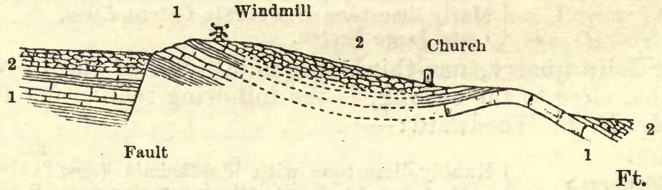
They were shown in separate pits at Log Farm near the Ray.

The white limestone does not crop out at Oddington, but it was seen by Prof. Green in a quarry, now disused, south-west of the Church.

		Ft.	in.
Forest Marble ...	Flaggy oolitic limestone, full of broken shells...	1	0
	Sandy clay and rubble	1	0
	Flaggy limestone (as above), with *Ostrea*	1	3
	Pale blue clay...	3	0
Great Oolite ...	White clay, mixed with limestone-rubble	1	0
	Solid whitish limestone, very oolitic.		

The same author has given the following section at Charlton:—

FIG. 3.—*Diagram section through Charlton.* (*A. H. Green*).[3]



		Ft.	in.
2. Cornbrash ...	Rubbly limestone...	2	0
1. Forest Marble	Flaggy oolitic limestone	0	6
	Yellowish marl	0	3
	Soft whitish oolitic limestones	3	0
	Pale blue clay	—	

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[1] *Rep. Brit. Assoc.* for 1860, p. 106; Green, Geology of Banbury, p. 29; Lycett, Supp. to Great Oolite Mollusca, p. 64; Phillips, Geol. Oxford, p. 153.

[2] Green, *op. cit.*, p. 35; Hull, Explan. of Hor. Sections, Sheets 71 and 72; *Geol. Survey*, p. 3.

[3] Geology of the country round Banbury, &c., 1864, p. 36.

CHAPTER III.

MIDDLE OOLITIC ROCKS.

BY H. B. WOODWARD AND T. I. POCOCK.

OXFORD CLAY AND KELLAWAYS BEDS.

This formation takes its name from the county of Oxford, where it enters extensively into the structure of the ground; moreover, it is exposed in the neighbourhood of the City of Oxford in several brickyards which appropriately furnish some of the larger inland sections of the formation.

The Oxford Clay consists of bluish or greenish and lead-coloured clay, which usually becomes brown or yellowish-grey at the surface. In many places, and more especially in the upper part, the bedding in the clay is not distinct, and is marked only by bands of septaria and occasional layers of earthy limestone; but lower down the formation is usually more shaly, and this character is maintained even when the beds come near the surface. The shale is grey and reddish-brown or purple in colour. Both clay and shale are often calcareous, and occasionally bituminous; and lignite is sometimes met with.

Septaria occur at irregular intervals and they may attain a large size, having a diameter of 3 feet or more. The beds contain much iron-pyrites and selenite; and many of the fossils are of a pyritic character.

The hard sandstones near the base of the Oxford Clay, to which the name Kellaways rock was originally applied in Wiltshire, are represented in the neighbourhood of Oxford by sandy and loamy beds that have been exposed near Bicester, and on the branch railway to Woodstock, to the north of the area. (See p. 17.)

Here, as in many other localities, there is from 10 to 12 feet of clay at the base of the Kellaways Beds. Doggers of calcareous sandstone often occur in the sands of this subdivision.

The Oxford Clay, which is estimated to be nearly 400 feet thick in this region, occupies an area almost as great as that of all the other strata taken together. Rising in somewhat bold and rounded hills above the Great Oolite Series, the lowest zone of this formation spreads from the Windrush, near Witney, by Osney Hill and North Leigh to Hanborough on the Evenlode, and thence by Bladon Heath to the Cherwell, beyond which it passes northward outside our region. The upper zone forms the lower slope of the Corallian escarpment, which runs with broad curves from Hinton Waldrist to Cumnor, and round Wytham Hill to the Hinkseys, and from Iffley by Elsfield, Beckley and Studley, to the north of Muswell Hill. South-eastward of Ot Moor the outcrop is prolonged, by the removal of the overlying Corallian Beds, almost to the Thame at Waterperry. Through the middle of this broad tract flows the River Thames as far as the gap in the Corallian formation below Iffley, and much of the surface of the clay is covered by sediments laid down by the river at former stages of its history.

The Oxford Clay has been divided into the following Ammonite zones:—

Cardioceras cordatum	Clay with septaria and ironstone nodules. Clay with pyritic fossils (subzone of *Quenstedtoceras Lamberti*).
Cosmoceras ornatum	Shales with pyritic fossils (subzone of *Cosmoceras Jason*).
Kepplerites calloviensis	Clay and shale with sand-beds and concretionary masses near the base (Kellaways Rock). Clay (Kellaways Clay).

The lowest zone may be said generally to be that part which comes to the surface north-west of the Thames alluvium as far as Yarnton, and in the vicinity of the Lower Oolite inliers by Ot Moor. The middle zone is, to a large extent, covered by alluvial deposits, while the upper zone forms the sloping land leading up to the Corallian escarpments.

The sands of the Kellaways Beds are seldom to be seen; they are marked by a belt of marshy ground with springs, which is usually found shortly after passing from the Cornbrash to the Oxford Clay area; and they are accountable for the somewhat sharp feature with which this formation rises above the rocks below, as in Burleigh Wood, south-west of Bladon, and to the east of Church Hanborough. From time to time these basement-beds have been opened in the railway-cutting at Islip Station, where they are faulted against an inlier of Lower Oolitic rocks. Numerous doggers have been found with *Kepplerites calloviensis.*

Between Long Hanborough and North Leigh at "the Demesnes," where drift-gravel is obtained for road-metal, a few feet of the lowest zone of Oxford Clay are exposed. Two distinct types are to be seen. Below are dark purplish shales, while directly under the drift is a tough clay of paler greenish colour with mottled veins of red. No fossils were observed here, but in the foundations of the new hall in Eynsham Park, where similar beds were to be seen, some fragile Ammonites were obtained.

The brick pits at the north-east corner of the Park and on the top of Combe Hill also show clay at nearly the same horizon.

North of the city of Oxford deeper excavations have been made, of which the following particulars have been given by Mr. Woodward. On the Woodstock road near Summertown, there is a large pit, where, beneath eight or ten feet of valley-gravel, the Oxford Clay, consisting of bluish-grey or lead-coloured clay with occasional scattered septaria, has been dug to a depth of about 40 feet. Some of the septaria contain lignite. The clay is slightly calcareous, and many of the Ammonites are pyritized. *Cardioceras cordatum* occurs in the upper part, together with *Gryphœa dilatata,* and lower down we find *Cosmoceras Duncani, Quenstedtoceras Lamberti, Belemnites hastatus, B. sulcatus,* &c.; likewise, *Kepplerites* *calloviensis, Macrocephalites macrocephalus, Peltoceras Williamsoni,* and *Nucula ornata.* Thus portions of the chief zones of the Oxford Clay are here represented.

The occurrence of fossils belonging to the three main zones is confirmed by specimens in the Oxford Museum and in the collection of Mr. James Parker. These include, in addition to some of those mentioned above, *Peltoceras athleta, Œkotraustes crenatus, Cosmoceras gowerianum, Cosmoceras Jason, Quenstedtoceras Mariæ,* &c.[1] No doubt the beds at Summertown should be grouped mainly as the zone of *Cosmoceras ornatus*—regarding that as a general palæontological horizon.

Close by the railway-tunnel at Upper Wolvercot, there is another large pit showing 40 feet of Oxford clay, with gravel and loam on top, similar to the section at Summertown. The septaria are scattered, there being no conspicuous band of them. Among the fossils *Gryphœa dilatata* and *Belemnites sulcatus* are most abundant. *Kepplerites calloviensis* also occurs. Half a mile further on the Woodstock road 20 feet of clay has been dug at the brickyard on Peartree Hill.

In St. Clement's, south-east of the city, owing to the prevalent dip of the strata in that direction, the higher zone of the Oxford Clay is exposed in the brick pits. From the pit near the workhouse on the Cowley road, Mr. H. B. Woodward obtained *Cardioceras vertebrale, Belemnites excentricus, B. Oweni,* and *Gryphœa dilatata.* Other species from this locality in the Oxford Museum and in the collection of Mr. James Parker, include *Cardioceras cordatum, Quenstedtoceras Lamberti, Belemnites hastatus, B. sulcatus, Rhynchonella varians, Pentacrinus Fisheri*; also *Asteracanthus* and *Hybodus,* as well as Saurian and Crustacean remains, the latter comprising *Glyphea, Eryma,* and *Goniocheirus.*

The pit by the roadside, half-way between Magdalen Bridge and Marston, showed 20 to 30 feet of clay belonging to the Upper Zone.

In the great tract of Oxford Clay south-east of Ot Moor there is only one section to record. This is the small brickyard by the roadside half a mile south-east of Studley. The clay belongs to the Upper Zone and yields *Cardioceras vertebrale,* and the characteristic *Gryphœa dilatata.* But though sections are few in number, the gryphæas occur in such profusion that it is only necessary to walk over land directly below the Corallian escarpment to pick them up in abundance from the ploughed fields, ditches and ponds.

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[1] See Phillips, Geol. of Oxford, p. 304.

CHAPTER IV.

MIDDLE OOLITIC ROCKS—(*continued*).

BY T. I. POCOCK, WITH NOTES BY H. B. WOODWARD.

CORALLIAN.

Between the Oxford Clay and the Kimeridge Clay there is a variable series of sands and rock-beds that are well shown in quarries near Abingdon, and in the neighbourhood of Oxford. They are again seen at Upware, near Cambridge; but over the chief part of the area between Wheatley, east of Oxford, and North Lincolnshire, this intermediate formation is represented mainly by the Ampthill Clay.

Buckland, in 1818, divided the rock-beds near Oxford into Calcareous Grit, Coral Rag, and Upper or Oxford Oolite.[1]

Since then, our knowledge has been largely amplified by Fitton, John Phillips, and especially by Prof. J. F. Blake and Mr. W. H. Hudleston, who, in 1877, gave a very full description of the strata and their fossils.[2] Grouped now as Corallian, the rocks admit, near Oxford, of the following general divisions:—

Upper Corallian	Coral Rag and Coralline Oolite (12 to 40 ft.)	Zone of *Perisphinctes plicatilis*
Lower Corallian	Calcareous Grit and Sands (20 to 60 ft.)	Zone of *Aspidoceras perarmatum*

At Marcham and Oxford the upper division comprises rubbly coral-limestones, with local sandy and clayey intercalations; and with calcareous grit and sands beneath. In some places these are so intimately connected that we can fix no definite plane of separation; elsewhere they are clearly marked off one from the other, and there are indications of local erosion. Near Wheatley beds of oolite and shelly limestone are intercalated in the Upper Corallian division.

Among the fossils of the Calcareous Grit perhaps the most remarkable is the Ammonite *Aspidoceras perarmatum*, which occurs at Marcham and other localities, with the chambers only preserved in the form of casts. Specimens of this kind were named "*Ammonites catena*."[3] The interior of the Ammonite was filled with ferruginous and calcareous mud or sand, and the shell and septa have subsequently been dissolved away, leaving only the casts of chambers in a loose form or linked together so as to resemble a rough tapering chain. *Cardioceras cordatum* also occurs in the form of casts.

Among Corals, the "Honeycomb Coral," *Isastræa explanata*, so abundant at Headington, also *Thecosmilia annularis*, and *Thamnastræa arachnoides*, are those more commonly to be obtained.

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[1] Table appended to the Outline of the Geology of England and Wales, by William Phillips, 1818.

[2] *Quart. Journ. Geol. Soc.*, xxxiii. p. 389; *Geol. Mag.*, 1878, p. 91.

[3] See Sowerby, "Mineral Conchology," v., p. 21.

Dr. J. F. Whiteaves many years ago zealously collected the fossils from the Corallian rocks of Headington, Bullingdon, Cumnor, Bessels Leigh, and Marcham, but he did not separate the species from the Lower Calcareous Grit and the Coral Rag, as the boundary between the divisions had "not been accurately defined."[1] Subsequent research shows that there is indeed no definite boundary, and that the divisions, though marked in some places, are for the most part arbitrary.
H. B. W.

Longworth and Kingston Bagpuize.

One of the best sections of the Corallian rocks was exposed in a quarry by the Lamb and Flag Inn, south of Longworth, and about two miles west of Kingston Bagpuize[2]:—

		Ft.	in.
Soil ...	12. Reddish-brown earth ... ... about	3	0
Upper Corallian	11. Marly bed...	0	6
	10. Flaggy and gritty oolitic stone	1	0
	9. Oolitic sandy débris, with dark clayey streaks, and occasional lydite pebbles: *Echinobrissus*	1	0
	8. Laminated clay and sand with irregular white calcareous seams	7	0
	7. Oolitic limestone; few fossils	1	6
	6. Marly oolitic layer: *Pleuromya*... ...	0	6
	5. Hard pale grey shelly limestone. *Trigonia*-bed: *Cardioceras cordatum*, *Trichites*, and casts of shells at base	1	8
	4. Brown earthy rock with casts of shells, *Pleuromya*, &c.: passing down into blue rubbly pisolitic rock, and this merges into bed below	2	0
	3. Grey shelly limestone, oolitic and pisolitic, with rolled fragments of hard limestone, bored by Lithodomi and encrusted with Serpulæ: small pebbles of lydite and quartz	1	6
Calcareous Grit	2. Hard grey calcareous grit, impersistent	3	0
	1. Buff sands.		

The main mass of shelly and oolitic limestones varies from about seven to twelve feet in thickness.

Among the fossils from the beds 3 to 7, but chiefly from bed 5, are *Perisphinctes plicatilis*, *Cardioceras cordatum*, *Belemnites abbreviatus*, *Modiola cancellata*, *Trigonia perlata*, *T. Meriani*, *Trichites*, *Gervillia aviculoides*, *Alectryonia gregaria*, *Perna mytiloides*, *Hinnites tumidus*, *H. velatus*, *Pecten demissus*, *P. fibrosus*, *P. lens*, *Lima pectiniformis*, *L. rigida*, *Echinobrissus scutatus*, &c. Many of these and other species were recorded by Messrs. Blake and Hudleston.[3] They noted that the upper sandy and clayey beds (8 and 9) rested unconformably on the limestones below. There is also indication of a local break at the base of bed 3.

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[1] *Ann. and Mag. Nat. Hist.*, ser. 3, viii., 1861, p. 142.

[2] H. B. Woodward, "Jurassic Rocks of Britain," v., pp. 122, 123.

[3] *Quart. Journ. Geol. Soc.*, xxxiii., p. 304.

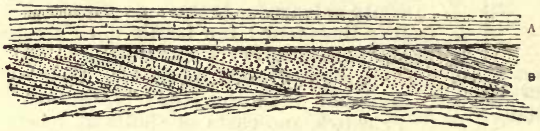
Prof. Hull[1] here grouped the top strata of sand and clay as "Upper Calcareous Grit," but there appears no justification for tracing such a subdivision on the map.

No Coral-beds were observed here, but they may have been removed by contemporaneous erosion. The whole section is a good illustration of the rapid alternations of different sediments that took place in the shallow waters of the Corallian period.

Other sections may be seen near Pusey Lodge Farm, and three-quarters of a mile south of Lower Lodge Farm. Eastwards, along the plateau, by the road from Kingston Bagpuize to Fyfield, the Calcareous Grit is quarried in several places for building-stone. A brown sandy and loamy soil covers much of the area in this neighbourhood.

Professor Hull figured a section a quarter of a mile east of Kingston Bagpuize, where the Lower Calcareous Grit is very obliquely bedded and pebbly. He estimated the total thickness of the Calcareous Grit at from 20 to 80 feet, and the Upper Corallian at about 10 feet.[2]

FIG. 4.—*Quarry near Kingston Bagpuize, west of Abingdon.* (*Prof. E. Hull.*)



A. Upper Corallian (Coral Rag). Rubbly and shelly limestone, with casts of shells; few Corals.

B. Lower Corallian (Calcareous Grit). Irregular beds of calcareo-siliceous rock, conglomeratic; fossils fragmentary; alternating with coarse brown siliceous sand, with pebbles of quartz, lydian-stone, &c. Beds obliquely laminated.

This is probably the quarry at the cross-roads south of Woodhouse Farm. Very similar beds were shown in a pit half a mile further on towards Abingdon.

A mile east of Tubney, near the cross-roads, a good section showing the Calcareous Grit has recently been reopened after the quarry had been disused for many years. The beds are mostly yellow sand, but they are indurated in bands and irregular masses, which are much broken and iron-stained. At a depth of about 10 feet is an intensely hard blue gritstone with shale-galls, lignite, and casts of shells; this rock was quarried for building-purposes. The sand is in part the decalcified remnant of calcareous sandstone.

Marcham and Appleton.

The well-known quarries of Marcham show the most complete series of Corallian strata to be found in the district. In the pit by Sheepstead Farm is seen for the first time the Coral reef, which, from here till the formation dies away to the north-east of Shotover Hill, is a characteristic feature of the rock-plateau overlooking the Oxford plain. In the same quarry the *Trigonia*-limestone, which was seen at

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[1] Geol. Parts of Oxfordshire and Berkshire, p. 7.

[2] Geol. Parts of Oxfordshire and Berkshire, p. 6; see also Explan. Hor. Sec., sheet 72, p. 7.

Kingston Bagpuize, and the Calcareous Grit are shown below the Coral-beds. The two former divisions only are found in the next quarry to the east, near Gosford, but a mile to the west of Marcham the complete sequence occurs again near the Noah's Ark Inn, though it is not so well seen as formerly.

The general section at Marcham noted by Mr. Woodward is as follows[1]:—(See Fig. 5.)

		Ft.	in.
Upper Corallian	7. Red and brown earthy soil.		
	6. Impure, slightly oolitic limestone, passing down into rubbly coral-rock and clay	6	0
	5. Oolitic and sandy marl, passing down into earthy oolitic limestone and rubbly oolite, with *Trigonia*-bed 4, at base. This fossil-bed tapers away towards the western part of the Sheepstead Farm quarry	2	6
	3. Reddish brown and white shelly sands, with indurated fissile beds and laminated clay; pebbly layer at base, when resting directly on the Calcareous Grit ... ... 2 ft. 6 in. to	4	0
	2. Oolitic, flaggy and gritty limestone, 1 foot, tapering away eastwards in the Sheepstead Farm quarry, and replaced by rubbly oolite, and by a conglomeratic band with pebbles of lydian stone, oolite and bored limestone. In the quarry to the north-west this fossil-bed is again seen, where it is 2 feet thick and conglomeratic. It contains *Serpula*, *Trigonia* and many Lamellibranchs; also *Natica marchamensis*	1	0
Lower Corallian (Calcareous Grit)	1. Hard calcareous sandstone (1 ft.), *Natica*-bed (of Blake and Hudleston), with *N. marchamensis*: in some places united to the fossil-bed above, in other places separated by a thin bed of shelly sand (6 in.), with *Exogyra nana*, *Gervillia*, *Pecten fibrosus*, and *Ostrea solitaria*... ... ... False-bedded buff and ochreous sands with ironstone concretions, streaks of clay, pebbles of quartz, and lydian stone: *Alectryonia gregaria*, lignite, &c. Here and there the mass of the strata up to the base of the Upper Division consists of layers of fissile calcareous sandstone occasionally ripple-marked; in other places there are only impersistent and irregular layers and doggers of sandstone	8	0

In the Upper Corallian Beds the higher *Trigonia*-bed yields *Perisphinctes plicatilis*, *Belemnites abbreviatus*, *Astarte ovata* (Smith)[2], *Lima pectiniformis*, *Trigonia perlata*, *Alectryonia gregaria*, *Echinobrissus scutatus*, *Pygaster umbrella*, Lignite, &c. The lower fossil-bed is also a *Trigonia*-bed. The presence of sandy beds among the fossiliferous Upper Corallian

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[1] "Jurassic Rocks of Britain," iv., p. 124. The pit at Sheepstead Farm was formerly known as the Oakley House quarry.

[2] Preserved in the Museum of Practical Geology.

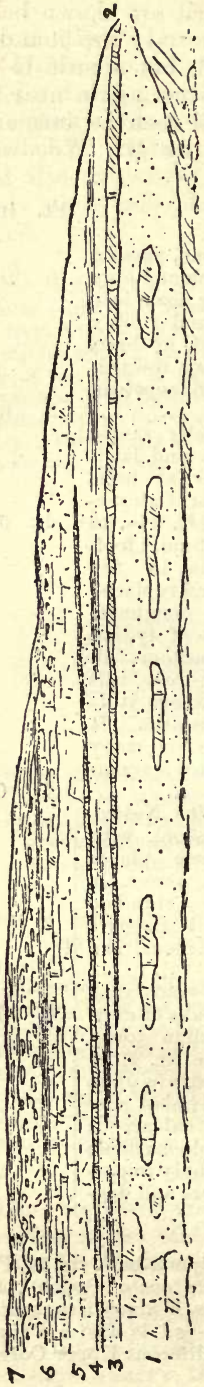

FIG. 5.—*Section at Marcham, near Abingdon.* (*H. B. W.*)

7. Red earthy soil.
6. Rubbly coral-rock and clay.
5. Marl and rubbly oolite.
4. *Trigonia*-bed.
3. Laminated clay and shelly sand.
2. Oolitic shelly limestone (fossil-bed).

} Upper Corallian.

1. Sand and sandstone with concretionary masses of sandstone (Calcareous Grit). } Lower Corallian.

[For details see p. 29.]

rocks, and the occurrence of the two fossil-beds and their impersistent character, form interesting features.

The sands of the Calcareous Grit at this locality have been famous for fine examples of *Aspidoceras perarmatum* (see p. 26). Casts of *Cardioceras cordatum* are also met with. Here, too, *Hemipedina marchamensis* occurs.

The sections at Marcham, including a quarry at Noah's Ark further south, have been described by Messrs. Blake and Hudleston, who record many fossils.[1] They drew attention to the evidences of local erosion, but the lower fossil-bed was not exposed at the time of their visit.

The irregular cementation of the sands of the Calcareous Grit into doggers and into bands of sandstone was well shown in the quarries near Marcham.

H. B. W.

Northwards from Abingdon, along the Cumnor road, small openings show the Coral beds with a variable thickness of weathered rock at the top.

At Dry Sandford, to the west, the two Corallian divisions are again seen as follows:—

		Ft.
Coral Rag	Coral rock and rubble ...	3
Calc. Grit	Buff sand with tufaceous rock containing univalve shells ...	3

These show that the *Trigonia*-limestone beds, very well developed farther west, have completely died away, so that the Coral-bed reposes directly on the sands and grits of the Lower Division.

Sections of the Lower Division may be observed at Cothill and to the south-east of Appleton, where 12 feet of buff sand with shelly rock were exposed.

Cumnor.

To the south-east of Cumnor, and near Bradley Farm, as observed by Mr. Woodward, there are several quarries in the Corallian rocks, the sequence being as follows[1]:—

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[1] *Quart. Journ. Geol. Soc.*, xxxiii., pp. 305, &c.; see also H. B. Woodward, *Proc. Geol. Assoc.*, xii., p. 331.

		Ft.	in.
Upper Corallian	Coral-rock with interbedded tufaceous stone, like that at Wheatley ... 4 0 to	5	0
	Hard beds of Coral-rock as at Purton, with *Thecosmilia annularis, Lithodomus inclusus*, and spines of *Cidaris florigemma*; passing down into sandy shelly and tufaceous rock of variable character (as at Wheatley), with *Pecten, Ostrea, Exogyra, Lima rigida*, &c.	8	0
Lower Corallian	Brown and grey sands, shelly in places ...	5	0
	Calcareous sandstone, two or three thick beds	3	6
	Buff sand and laminated clay	4	0

The beds indicate irregular accumulation. From the Calcareous Grit at Bradley Farm, Messrs. Blake and Hudleston record *Aspidoceras perarmatum*, *Cardioceras vertebrale*, and a number of Gasteropods, including *Cylindrites Luidi*. This is one of the most fossiliferous beds in the Corallian series. With regard to the Coral Rag, they observe that "the reef-corals here are in a more perfect state of preservation than in any locality we know of." I obtained a fine specimen of *Isastræa explanata*.

Lycett recorded *Trigonia triquetra* Seeb. from the Calcareous Grit of Cumnor.[2]

H. B. W.

An important stream takes its rise at Cumnor Village, near the top of the Calcareous Grit, being probably thrown out by the clay above noted.

Wytham and North Hinksey.

On the Wytham Hills there is an outlier two miles long of Corallian strata, separated from the main outcrop by the deep valley through which the road from Oxford to Eynsham passes. Though apparently simple in structure, the rocks in these hills show signs of considerable disturbance when the boundaries are traced on a contoured map. On the slope overlooking the Upper Thames or Isis, the strata are nearly horizontal, for on western scarp of Wytham and the neighbouring little outlier of Beacon Hill the base of the Calcareous Grit is at almost the same elevation. But at the *col* between Wytham and Seacourt Hills the boundary-line rises considerably, and falls something like 100 feet towards Wytham, and 200 towards Botley. The dip on the south side of the hill is great enough to bring the Corallian Beds to the river-level between Botley and North Hinksey. Hence it follows that there is a considerable displacement between the Wytham and Cumnor Hills, which cannot be less than 50 feet, and may be nearly 100. Whether this is due to a synclinal fold or to a fault, the evidence in the field is not sufficient to determine, but the latter explanation seems more probable.

The Wytham Hills are in line with the Oolite inliers extending from Islip towards Buckingham, and the undulations of the strata are probably the feeble continuation of the sharp folds which bring the lower formations to the surface along that region of upheaval. The old quarries seen at the top of Wytham Hill, particularly near the western edge, were probably worked when the main road from Oxford crossed the high ground before the present lower road was made. They well show the Coralline limestone of the Upper Division, as also do the other quarries on Seacourt Hill. Near the east side of Wytham Great Wood there are sand-pits in the Calcareous Grit. Much of the ground occupied by the Coral Rag is, however, sandy, and this division apparently exceeds the lower in thickness.

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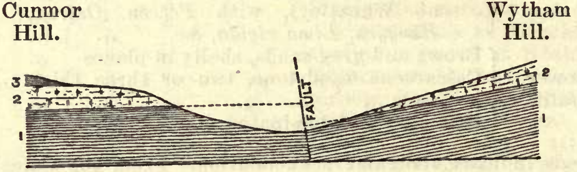
[1] Hudleston, *Proc. Geol. Assoc.*, vi., p. 343; Blake and Hudleston, *Quart. Journ. Geol. Soc.*, xxxiii., p. 307.

[2] Brit. Foss. Trigoniæ, *Pal. Soc.*, p. 27.

FIG. 6.—*Section across the Botley Valley between Cumnor and Wytham Hills.*



1. Oxford clay. 2. Corallian. 3. Kimeridge clay.

On Wytham Hill the base of the Calcareous Grit is from 110 to 190 feet below the summit; that of the Coral Rag 50 to 150 feet. The corresponding figures for Seacourt Hill are 60 to 210, and 25 to 190. The narrowness of the outcrop of the Lower Division in many places along the hillside, shows that there cannot be more than 20 or 30 feet of it. But the great vertical range of the Rag above it, gives an erroneous impression of its thickness, and tends to show that Wytham and Seacourt Hills are separate anticlinal domes, though the dip of the strata in any direction probably does not exceed 4°. The importance of the structure of this hill will be pointed out when the physical features of the district are described.

A section, now much overgrown, was described by Mr. Woodward a quarter of a mile south-west of North Hinksey:—

		Ft.	in.
Upper Corallian	Rubbly Coral-rock with much clay; spines of *Cidaris, Lithodomus*, &c.	8	0
	Hard sandy oolitic limestone with small pebbles: merging upwards into Coral-rock; *Ostrea solitaria, Pecten articulatus*, &c.	1 0 to 2	0
Lower Corallian	Buff sands, with beds of hard calcareous sandstone	10	0

The hard bed below the Coral-rock presents an aspect similar to beds of Wheatley stone. Good sections of like character may also be seen near the brook which runs from Boar's Hill to South Hinksey, not far from where the Abingdon road turns into Bagley Wood.

Kennington and Radley.

Hitherto the Corallian rocks have formed a well-defined dip-slope half a mile to a mile broad, truncated by bluffs along the right bank of the Isis; but at Bagley Wood the outcrop is confined within very narrow limits by the covering of Kimeridge Clay, and though it is prolonged for another two miles down the river, it does not again attain its former width. The brooks in the northern part of Bagley Wood, though difficult of access, owing to the thick undergrowth, expose most of the beds from the Oxford to the Kimeridge Clay. The former extends up the combe past the confluence of the two brooks, but its outcrop is too narrow to be shown on the one-inch map.

At Kennington the Coral Rag may be seen close by the church, and immediately below, at the top of the lane leading towards the railway, are large slabs of Calcareous Grit apparently *in situ.* The next brook to the south, opposite Sandford Pool, also shows here and there sections of both divisions. Sand with large masses of calcareous sandstone occurs in the adjacent railway-cutting.

The formation finally passes out of sight under the Kimeridge Clay of Radley Large Wood.

In the deep hollow at Sunningwell, south of Foxcombe Hill, a narrow outcrop of Coral Rag appears, which is either an inlier, or connected by the brook bed with the main outcrop to the south-west.

Headington and Littlemore.

The following notes are by Mr. Woodward:—

To the east and south-east of Oxford the Corallian Beds are divisible into two portions : an upper one of limestones largely made up of corals and comminuted shells and corals, and a lower one of sands with indurated bands and concretionary masses of calcareous sandstone (Calcareous Grit).

The upper division of Coral Rag is variable: in some places it consists of impersistent layers of hard grey shelly limestone (which has been employed for building-purposes) alternating with shell- and coral-sand; in other places it comprises irregular bands of coral limestone and clay. The quarries show from 10 to 25 feet; but the beds thicken towards Wheatley, and the total thickness was estimated by Phillips at 40 to 50 feet.

Conybeare observed that the upper surface of the freestone-beds, beneath the Kimeridge Clay, bore evidence of water-action.[1] Buckland and De la Beche, and later on John Phillips and others, have also remarked that the Kimeridge Clay rests on a waterworn surface of the Corallian Beds. This can, of course, only be seen when a good surface of the top stone is bared; moreover, the change in conditions is abrupt, and as remarked by Mr. Hudleston, "there appears to be a very marked break."[2]

There are numerous quarries at Headington, and the junction with the Kimeridge Clay was well shown in the pit to the left of the road leading from Oxford to Shotover Hill. The section was as follows:—

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[1] Geol. Eng. and Wales, 1822, p. 189; See also Sedgwick, *Ann. Phil.*, xxvii. (ser. 2, xi.), p. 350; Buckland and De la Beche, *Trans. Geol. Soc.*, ser. 2, iv., p. 26; Phillips, Geol. Oxford, &c., p. 299; and James Thorne, "Excursion to Oxford," *Rep. Geol. Assoc.*, 1869, separately printed, p. 6.

[2] Report of Sub-Committee on Classification, Internat. Geol. Congress, 1888.

			Ft.	in.
Kimeridge Clay	Dark bluish-grey clay Grey racy clay	Saurian bones, *Ammonites*, *Ostrea deltoidea*, large crystals of selenite		
Upper Corallian	Marly layer ... ... False-bedded sandy rock (decomposed) and passing down into bed beneath		1	0
	Hard grey shelly limestone ...		1	6
	Coral-rock, with bands of hard grey shelly limestone (building-stone); few fossils		12	0

Here the total thickness of the Upper Corallian Beds, down to the Calcareous Grit, is about 30 feet. In some quarries the beds are more fully exposed, and their variable character is manifest. We find coral rock, shelly sand, and lenticular layers of hard grey oolitic and shelly limestone; the whole irregular and false-bedded. In places the bottom-bed, as at Littlemore, is a shelly calcareous gritty rock (2 feet to 2 feet 6 inches thick); and this rests on brown sands with concretionary beds of calcareous sandstone (Calcareous Grit). In other places Messrs. Blake and Hudleston have noticed on top of the Grit a pebbly bed (about eight inches thick), with rolled oolite, and nodules with *Cardioceras cordatum*, and containing also *Ostrea solitaria*, *Avicula expansa*, *Lima læviuscula*, and *Natica Clytia*.[1]

A quarry south of Bullingdon (or Bullington) Green, east of the cross-roads between Temple Cowley and Horsepath, showed the following section:—

		Ft.	in.
Upper and Lower Corallian	Rubbly coral-beds, with much clay, and with shelly sand at base; *Pleurotomaria reticulata*, *Exogyra nana*, &c.	3	0
	Tufaceous sandy rock	0	8
	Shelly sand, with *Aspidoceras perarmatum*, *Chemnitzia*, *Ostrea*, *Pecten*, *Serpula*, &c.	0	8
	Shelly calcareous grit	1	2
	Sandy bed	0	6
	Shelly calcareous grit, slightly oolitic	1	6
	Sand	1	0

Here it is difficult to mark a division between Upper and Lower Corallian, though comparing the section with that of Littlemore, it might be taken just above the basement sand. The presence of *Aspidoceras perarmatum* is interesting.

The Coral Beds yield many of the Echinoids *Pygaster umbrella*, which are known to the quarrymen as "Mushrooms." Mr. James Parker has obtained Fish-remains, *Asteracanthus* and *Lepidotus*, from this locality.

The commoner fossils of the Upper Corallian Beds of Bullingdon and Headington are noted in the accompanying list. It is curious that the *Chemnitzia heddingtonensis* is stated by Sowerby to have been received "from Heddington, near Calne, in Wiltshire"; though he also mentions that he had found specimens about Shotover Hill (= Headington) in Oxfordshire.[1]

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[1] *Quart. Journ. Geol. Soc.*, xxxiii., pp. 308, 309.

LIST OF FOSSILS FROM THE UPPER CORALLIAN BEDS OF HEADINGTON AND BULLINGDON.

Perisphinctes plicatilis (*J. Sow.*).
—— varicostatus (*Buckl.*).
*Belemnites abbreviatus *Mill.*
Bourguetia striata (*J. Sow.*).
Chemnitzia heddingtonensis (*Sow.*).
Natica Clytia *d'Orb.*
*Pleurotomaria reticulata (*J. Sow.*).
Astarte ovata (*W. Smith*).
Avicula expansa *Phil.*
Corbicella lævis (*J. de C. Sow.*).
*Gervillia aviculoides (*J. Sow.*).
*Exogyra nana (*J. Sow.*).
*Goniomya v.-scripta (*J. Sow.*).
*Isocardia.
Lima elliptica (*Whit.*).
*—— læviuscula (*J. Sow.*).
*—— rigida (*J. Sow.*).
*Lithodomus inclusus (*Phil.*).
*Myacites.
Myoconcha Sæmanni *Dollf.*
*Ostrea solitaria (*Sow.*).
*Pecten articulatus (*Schloth.*).
*—— fibrosus *J. Sow.*
—— lens *J. Sow.*
Perna mytiloides *Lam.*
*Pholadomya æqualis *J. Sow.*
Pinna ampla *J. Sow.*
Trichites Ploti *Lhwyd.*
*Trigonia.
*Serpula tricarinata (*J. de C. Sow.*)
Astropecten rectus *McCoy.*
*Cidaris florigemma *Phil.*
*Echinobrissus scutatus (*Lam.*).
*Hemicidaris intermedia (*Flem.*).
*Pygaster umbrella *Ag.*
Pygurus.
*Isastræa explanata (*Goldf.*).
*Thamnastræa arachnoides (*Park.*).
*Thecosmilia annularis (*Flem.*).
Lignite.

* Species so marked were obtained by H. B. Woodward, and named by Messrs. G. Sharman and E. T. Newton; many of these and others have been recorded by Phillips, Geol. Oxford, &c., p. 300; by Blake and Hudleston, *Quart. Journ. Geol. Soc.*, xxxiii., p. 309; Hudleston, *Proc. Geol. Assoc.*, vi., p. 342; and E. S. Cobbold, *Quart. Journ. Geol. Soc.*, xxxvi., p. 314.

At Sandford the Corallian plateau is deeply intersected by brooks descending from the high ground of Shotover, so that a part of the Coral Rag is severed and forms an outlier capped by a thin spread of Kimeridge Clay on the low hill between Littlemore and Iffley.

West of Littlemore Station, a cutting on the Oxford and Thame railway showed the following section:—

		Ft.	in.
Upper Corallian	Dark clay with paler marly beds ... Clays and soft white marly beds, with but few corals = "Coral beds"...	[15	7]
	Shelly sand, with *Natica corallina*... ...	2	0
	Hard calcareous sandy bed... 10 in. to	1	6
	Sand	2	6
	Shelly calcareous grit (employed for building railway bridges)... ...2 ft. [to	2	6]
Lower Corallian (Lower Calcareous Grit)	Buff sands with spherical and elongated concretionary masses of hard calcareous sandstone (blue hearted), 4 × 5 × 2 ft. and less in size, like the "doggers" in the Bencliff Grits of Weymouth: occasional streaks of clay	15	0

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[1] "Mineral Conchology," i., p. 86.

Here, as at Bullingdon, we have a difficulty in making any separation between Upper and Lower Corallian Beds; there seems to be no evidence of any local break, and the sandy strata below the Coral-beds are doubtfully referred to the Upper Corallian, though they appear to represent the fossiliferous beds of Fyfield and Marcham.

The beds undulate very much in the railway-cutting west of Littlemore Station, but the general inclination is westwards. In 1867 Mr. T. Codrington noted that there were numerous small faults in the cutting. "They show as faults in the rocky bands, but above, the clayey rubble-beds appear as if contorted—this is due wholly to the faults."[1] The clayey Coral-beds make heavy land on the slopes to the west.

The section at Littlemore was described by Mr. E. S. Cobbold, on whose authority we insert the thickness of the upper clayey and marly beds. He states that, in laying the sewage-pumping main along the road up Sandford Hill, there was a thickness of about 12 feet 6 inches of very hard fine-grained limestone above the marls; it occurred in three or four layers with hardly any fossils. Above this, again, there was a stratum of very sandy limestone, 2 feet 6 inches thick, suggesting a trace of "Upper Calcareous Grit." (See p. 28.)

A trial-hole on the Sewage Farm about a mile east of Sandford, showed the following section[2]:—

		Ft.	in.
	Soil	2	6
[Kimeridge Clay]	Clay	1	6
	"Oyster" bed	1	0
[Upper Corallian]	Brown earth	1	0
	Black earth	1	2
	Marl, rubble	1	2
	Hard blue stone	1	0
	Marly clay	0	9
	Blue stone	0	6
	Marly clay	5	0

The Corallian Oolite was not present, but in the opinion of Mr. Cobbold, "it had entirely changed its character in the short distance (one mile) from Sandford." He suggests that "the influx of clay may have been due to the muddy discharge from some river which might hinder or altogether check the growth of corals, while it was favourable to that of oysters," and that "the supposed river cannot have been very large or very far off." . . . "It seems therefore probable that the Palæozoic rocks known to exist beneath London may have been above water in the later Oolite period, and have had considerable extension to the S.W. and E."

In the several sections from Littlemore onwards we have indications of similar changes to those which the Corallian strata undergo to the north-east of Wheatley, and which presumably take place also to the south-east of that locality, and of Sandford.

H. B. W.

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[1] MS. note communicated to Mr. Whitaker.

[2] No. 3, Fig. 7, in paper by E. S. Cobbold, *Quart. Journ. Geol. Soc.*, xxxvi., p. 319. See also Prestwich, *ibid.*, p. 431; H. B. Woodward, *ibid.*, xlii., p. 307.

Elsfield and Beckley.

North of Headington the Corallian escarpment is deeply indented by a stream rising at Forest Hill, near Wheatley, which, with its tributaries gathered from the rock-beds, forms a considerable extent of marsh-land at the foot of the slopes.

Near Wick Farm the Calcareous Grit has a narrow outcrop, and is evidently much thinner than on the opposite side of the valley at Headington. At a small pit one-third of a mile N.N.W. of the farm, the Coral Rag is seen to consist of limestone-beds full of corals and crinoid stems, with also *Exogyra* and other fossils. In Wick Copse, hard by, the thickness of the lower division can scarcely exceed 20 feet; but near Elsfield it increases again. Indeed, so much of the formation appears to consist of sand, that no satisfactory boundary-line could be drawn between the two divisions.

At a pit a quarter of a mile from Stow Wood, on the road to Elsfield, 5 ft. of Coral-limestone, overlying a similar thickness of shelly limestone, was seen.

This quarry is close to the line of disturbance which was mentioned in the account of the Lower Oolites of Islip (p. 20). The faulting appears to be complicated, but owing to the meagre field-evidence it could not be deciphered in detail. The general effect in this region has been to throw down all the beds some 50 ft. on the south-west side of the disturbed area, as may be seen if the escarpment is viewed from the top of Noke Hill, near Islip. The crest is observed to be much higher on the left side of the road to Wheatley than on the right; this road being coincident with the fault where it reaches the brow of the hill. If the ground be examined more closely it will be seen that from the corner of Stow Wood, south-eastwards for about a mile, the rising ground on the one side consists of sands belonging to the Calcareous Grit, while at a lower level on the other side is the Coral Rag. Beyond this the evidence is not so clear, though the fault is very conspicuous in the vicinity of Forest Hill. The rolling character of the surface in the disturbed area contrasts with the prevailing flatness of the Corallian plateau at Headington.

Between Stow Wood and Woodeaton the Upper Corallian is thrown down almost to the bottom of the hill in a trough between the main fault and one close by on the south-west side, the displacement being probably nearly 200 ft. on one side, and upwards of 80 ft. on the other. At Druns Hill is a small outlier in which the beds have a well-marked inclination to the south, and are cut off abruptly in that direction against the Oxford Clay in the bottom of Woodeaton Wood. A disused quarry at the top of Druns Hill showed 6 ft. of well-bedded shelly limestone, with partings of marl full of specimens of *Exogyra*.

North-east of the faulted belt there is again much difficulty in drawing a line between the two Corallian divisions, on account of the sandy character of the whole series. A thickness of 40 or 50 feet of Calcareous Grit is shown near Beckley, but there is not more than 30 feet at Woodperry and Stanton St. John. In the road-section, now overgrown, at Woodperry, south-east of Beckley, Prof. A. H. Green observed a hard lime-cemented sandstone at the base of the formation, with a thin band of clay in the middle; the coral limestone at the base of the upper division is seen for the last time in a small quarry close to Woodperry House. At the top of the hill, half a mile along the road to Oxford, there is another quarry, in which higher beds of limestone are seen: they contain no coral growths, but are full of sea-urchins.

The strata were noted by Mr. Woodward as comprising hard crystalline oolitic limestone used for road-metal and rough walling; with also beds of "freestone," a softer rock, which hardens on exposure, and is used for building purposes. *Perisphinctes plicatilis* occurs here.

Stanton St. John, Wheatley, and Oakley.

BY H. B. WOODWARD.

Near Stanton St. John, rag-beds have been quarried, and there Messrs. Blake and Hudleston noticed the abundance of Echinoderms, *Cidaris florigemma*, *Echinobrissus scutatus*, and *Pseudodiadema versipora*; while Corals seem to be absent or very scarce.[1]

The section at the quarry, now disused, at the south-eastern end of the village of Stanton St. John, was given by Prof. A. H. Green as follows:—

		Ft.
Upper Corallian	Rubbly limestone, full of broken fossils... ...	3
	Yellow and brown sandy clay, with irregular beds of concretionary limestone, full of broken shells, *Ostrea sandalina* (= *Exogyra nana*), &c....	10
	Hard, dark-blue limestone	6

The sands of the Calcareous Grit have been largely worked between Elsfield and Beckley.[2]

At Stanton St. John, near the school, there is an old quarry in which there are exposed about 10 ft. of rubbly limestone and marly clay, overlying hard sandy limestone, 1 ft. to 1 ft. 4 in., and brown sands and sandy limestone, exposed to depth of 4 ft. There is here a gentle dip to the S.W.

North of the George Inn there is an old limestone pit, probably in the lower part of the Upper Corallian and in subjacent sandy series. *Gryphœa dilatata* was here met with.

Cherty sandstone occurs by the woodside east of Stanton St. John, not far from the junction of the Lower Calcareous Grit with the Oxford Clay.

At Shepherd's Quarry, south-west of Stanton St. John, where the strata have also a general south-westerly dip, the following section was noted:—

	Ft.
Grey soil	1
Reddish-brown brashy subsoil ... ...1 ft. to	3
Grey clay	1
Hard grey limestones, with bands of rubbly limestone and marl: spines of *Cidaris florigemma*, *Serpula*, *Belemnites*, *Exogyra nana* ... ... 12 ft. to	15

A good deal of "rock milk" coats the faces of the jointed limestones. Building blocks are obtained from the harder bands of grey limestone.

On the north-western side of Wheatley there are large quarries, where Corallian limestone is worked for building-blocks and lime-burning. The rock here forms part of the faulted belt that extends from Woodeaton to the south-eastern base of Red Hill, through Wheatley Village, beyond which there is no further exposure of Corallian limestone.

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[1] *Quart. Journ. Geol. Soc.*, xxxiii., p. 310.

[2] Green, Geol. Banbury, &c., pp. 43, 44.

Near to Red Hill are the Lyehill Quarries, where about 50 feet of Corallian limestone occurs in massive beds. Harder layers of shelly oolitic and pisolitic limestone are interbedded with softer layers, and near the surface these are disintegrated into crumbly beds of shell-sand from which fossils may readily be extracted. These are few in kind, but include *Cidaris florigemma* (spines), *Exogyra nana*, and *Ostrea*. The strata are inclined to the N.N.E., but it is not clear whether this apparent dip is the result of false-bedding, or only slightly so.

In the quarries at Wheatley Village the stone is worked to a depth of 30 or 40 feet. The mass comprises oolitic shell-limestone, in harder and softer bands. The harder bands are the more shelly, and they are blue-hearted; the softer bands are more oolitic. The shelly stone is burnt for lime, and the oolitic freestone (which hardens on exposure) is used for building-purposes. The upper layers are fissile, and there is much decomposed shelly sand and oolite, with about 2 feet of brown brashy soil.

The fossils at Wheatley include *Cidaris florigemma* (spines), *Serpula*, *Exogyra nana*, *Chemnitzia*, *Belemnites abbreviatus*, and *Perisphinctes plicatilis?* (J. Sow.); the last-named was found in the upper portion of the section, below the fissile bands. *Exogyra nana* is abundant throughout the beds. In the Oxford Museum there are remains of a Saurian jaw from this locality.

The quarry by the old "lock-up" at Wheatley is utilized in part for the reception of town "rubbish," an unfortunate and ill-advised proceeding, considering that much water for the supply of houses is obtained from this mass of limestone. Rubbish has also been shot into a disused quarry in the meadow further west, in proximity to a well. In this old pit the Lower Corallian was probably reached.

It is difficult to decide whether the old pits in the meadow between Wheatley Station and the town were wholly in Corallian rock or partly in Kimeridge Clay. No positive evidence was to be gathered, either from the pits or by enquiry in the village. Nor could any information be obtained respecting the pits in Shotover Park. That by the Steward's house is now a shrubbery, and dry—it was probably opened for stone. The pits further south show only clay, but may have been excavated through the Kimeridge Clay into the Corallian stone.

The general strike of the Corallian strata is from the north-west towards Wheatley railway-station, where the beds are faulted against the Kimeridge Clay, which lies to the south-west. This fault extends to the north of the railway towards Wheatley Bridge. The Corallian is likewise faulted along its eastern and north-eastern borders, between Wheatley and Holton, so that the limestones are preserved by a kind of step-faulting. The throw of the main faults is, however, modified by transverse faulting, as at Forest Hill, where the Portland and Shotover Beds are let down between Kimeridge Clay and Corallian by normal trough faulting. Moreover, the general line of fracture and displacement is continued in a south-easterly direction through Great Milton, where an inlying tract of Kimeridge Clay gives indication of disturbance.

The relations between the Kimeridge Clay of Waterstock, south of the Thame, with the clayey Corallian Beds on the north, were nowhere displayed. It seems evident that the Wheatley rock passes into thin sands and clays with *Exogyra*, and that the equivalents of this and of the lower division, with its occasional rock-bands, are not to be separated in the area to the north-east.

Messrs. Blake and Hudleston remark: "We are here, then, presented with the deposits which were formed on the extreme edge, not only of the coral reef, whose thickness would not account for so much false dip (which amounts in the most easterly quarry to 12°, and is even marked at 18° at another spot on the [Geological Survey] map), but probably of the Lower Calcareous Grit sandbank also—a conclusion which is supported by the fact of its apparent sudden termination eastwards." They add that "the Corallian formation has died out, not gradually, but suddenly, and the normal pelolithic formation reigns supreme."[1]

Since this Memoir was written Mr. A. Morley Davies has published the results of researches which he has carried on in this area since 1899. He has largely added to the previous knowledge, and particularly in respect to the cherty rock of Studley and Arngrove.[2] To this further reference will be made.

In Holton Park the Corallian stone is said to lie all to the west of the Mansion, the house itself being partly on made ground. Clay was dug on the island surrounded by the moat, the site of the old Hall. Pieces of cherty sandstone occur in some of the fields to the south of Holton Wood. At Holton Rectory Oxford Clay was proved to a considerable depth.

The following record of a well sunk to the south of Church Farm Moat was noted by J. H. Blake in 1897:—

		Ft.	in.
Corallian	Brown sandy and loamy soil	2	0
	Brown sandy oolitic loam with irregular patches and seams of grey clay... ...	5	0
	Rock band	0	4
	Brown and grey clay	3	0
	Hard yellowish-white speckled cherty rock, called "Pendle" by the well sinker: with *Pleuromya*	4	6
Oxford Clay	Blue sandy and shaly clay, with band of rock 2 ft. thick, and large *Gryphœa dilatata*...	6	0

The strata appeared to dip towards the north-east. The cherty rock above noted is evidently the same as the Arngrove Stone.

The boundary of the Corallian and Oxford Clays in the area north-east of Holton is very indefinite. The presence of Corallian clays is indicated in many spots by the abundance of *Exogyra nana*, while here and there large examples of *Gryphœa dilatata* are suggestive of the upper part of the Oxford Clay, in which these forms are usually abundant.

From Holton through Waterperry, Worminghall, and Ickford the only sections are in ponds and ditches. The soil on the Corallian tracts is of variable texture, being here and there sandy and loamy, elsewhere clayey, but in general it is a "deepish loam."

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[1] *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 311.

[2] *Quart. Journ. Geol. Soc.*, lxiii., p. 29.

It was the opinion of Mr. T. R. Polwhele, who was engaged on the earlier Geological Survey, that along this belt there were argillaceous equivalents of the Lower Corallian Beds; while Prof. Green suggested that these clayey beds might be the equivalent of the Tetworth (Ampthill) Clay described by Prof. Seeley.[1] Lists of fossils from Ickford, Worminghall, and Oakley were given by Prof. Green, but the particular localities and horizons were not sufficiently distinguished.

At Worminghall, especially on the north side of the village, the ground has been dug up in places in "hills and hollows" as if for stone-layers.

In this neighbourhood, blocks of Corallian stone are brought to preserve entrance tracks to fields, and they are strewn about the approaches to ponds. On the whole the ground is clayey—cracked and fissured in dry weather—and the soil is a brown loam, stiff in some places, lightened elsewhere, as on some of the allotment grounds, by sandy and gravelly patches in the soil.

The soil is in part due to the decomposition of gritty and calcareous layers and stiff bluish and brown clay, with *Exogyra* and bits of large *Gryphœa*, as seen along the ditch on the north side of the road from Worminghall to Shabbington, north of Little Ickford.

Some of the hard beds from which water is obtained have probably become decomposed along their outcrop.

South of Oakley, at the end of the lane east of Shabbington Wood and north of Houndsditch Barn, I obtained *Alectryonia gregaria* (J. Sow.), *Exogyra* sp., *Gryphœa dilatata* J. Sow., and *Ostrea* (fragment).

Cherty sandstone occurs in a field south-east of Pasture Farm, west of Oakley. H. B. W.

Studley and Boarstall.

At Studley "a sort of argillaceous chert," which appears to have been first noticed by Buckland, was described by Prof. Phillips as containing *Ammonites*, *Pinna lanceolata*, &c. According to Prof. Green "This bed runs with a good escarpment by Arngrove Farm to the north of Gravel Pit Farm, beyond which point we lose sight of it altogether. It dips gently to the east, but whether it runs under the clay beds to the east of it, or passes into a clay, it is not easy to say. Immediately below this stone we find Oxford Clay with *Gryphœa dilatata*, and it is therefore without doubt the bottom bed of the Calcareous Grit." He recorded from it *Cardioceras cordatum* (J. Sow.), *C. vertebrale* (J. Sow.), *Pecten fibrosus* J. Sow, &c.[2]

Mr. A. Morley Davies has applied the name Arngrove Stone to the cherty rock, as "the chief present diggings are near Arngrove Farm, and as this is the only locality from which any abundance of fossils can be obtained."[3] It will therefore be convenient to adopt this name for local use. Mr. Davies has given detailed descriptions of the rock. The ordinary Arngrove Stone was observed by him

> "to be studded with innumerable minute ellipsoidal bodies, mostly of a translucent blue, but with everywhere some of an opaque white.

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[1] Green, Geol. Banbury, pp. 44, 45.
[2] Geol. Banbury, pp. 44, 45.
[3] *Quart. Journ. Geol. Soc.*, lxiii., 1907, pp. 37, 38.

> . . . It is neither calcareous nor purely argillaceous . . [and] as a whole, is very light and porous, absorbing water very readily." Under the microscope he found the grains "to agree exactly in size and shape with the globate spicules of the tetractinellid sponge, *Rhaxella perforata*, described by Dr. G. J. Hinde from cherts in the Lower Calcareous Grit of Yorkshire."

Mr. Davies further observed: "In one place only—at a pond-digging at the Warren Farm, north of Studley—this rock undergoes a remarkable change, becoming a limestone, though still exhibiting the characteristic structure."

Omitting the more doubtful forms, the following revised list of fossils from the Arngrove Stone was published by Mr. Morley Davies[1]:—

Cardioceras cordatum (*J. Sow.*)	D	S	P
——— vertebrale (*J. Sow.*)	D	S	P
Alectryonia gregaria ? (*J. Sow.*)	D		
Arca quadrisulcata (*J. de C. Sow.*)		S	
Avicula inæquivalvis *J. Sow.*		S	
——— ovalis *Phil.*	D		
Exogyra nana (*J. Sow.*)	D		
Goniomya literata (*J. Sow.*)			P
——— v.-scripta (*J. Sow.*)	D	S	
Lucina crassa ? (*J. de C. Sow.*)	D		
Modiola bipartita *J. Sow.*	D	S	P
——— cuneata *J. Sow.*			P
——— imbricata *J. Sow.*		S	
Pecten fibrosus *J. Sow.*	D	S	
——— lens *J. Sow.*	D		
Perna quadrata *J. de C. Sow*		S	
Pholadomya æqualis *J. de C. Sow.*	D	S	
——— obsoleta *Phil.*			P
Pinna lanceolata *J. Sow.*	D	S	
——— mitis *Phil.*			P
Pleuromya recurva (*Phil.*)	D		P
Trigonia clavellata ? (*J. Sow.*)	D		
Serpula	D	S	
Rhaxella perforata ? *Hinde*	D		

D.—Collected by A. Morley Davies.
S.— „ „ Geological Survey.
P.—Recorded by John Phillips.

Mr. Davies was enabled to observe the precise relation of the Arngrove Stone to the Oxford Clay in a well-sinking at the northern end of Studley Village, in September, 1899, the measurements given being approximate[2]:—

		Ft.
Soil and rubble of Arngrove Stone		3
Arngrove Stone		2
Reddish-brown sandy clay: fish-tooth, *Alectryonia* fragments, &c.		3
Argillaceous limestone	less than	1
Clay, very black and stiff: *Gryphœa dilatata*, *Cardioceras cordatum*	at least	10
		19

Between Beckley and Studley a deep valley connecting Ot Moor with the Thame basin, cuts off the Corallian rocks from the corresponding strata to the north-east; and when they are encountered again it is found that their character has completely changed. The escarpment, indeed, overlooking the Ot Moor plain, though lower than elsewhere, is still a conspicuous feature from Studley to the north of Muswell Hill beyond the limits of the district. But only an insignificant band of cherty stone 6 feet or less in thickness represents the 70 feet of strata at the top of Beckley Hill. There is no longer a continuous plateau of rock resting on Oxford Clay, but it is cut through by streams which, rising partly in the sands of Muswell and Brill, and partly in the plateau itself, have separated the rock bed into seven or eight outliers with valleys of greater or less depth in the Oxford Clay between. Further east the same bed is traceable continuously with clay-land on either side, from near Gravelpit Farm north of Boarstall, through the village, and southward past Slattery Farm, where it is lost sight of.

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[1] *Quart. Journ. Geol. Soc.*, lxiii., p. 43; see also E. T. Newton, *Proc. Geol. Assoc.*, xx., p. 127.

[2] *Quart. Journ. Geol. Soc.*, lxiii., p. 40.

It is clear from the manner in which the outcrop runs in V shapes up the brook-valleys, that this rock forms a gently inclined plane at the base of the clays to the east, which will be described later on under the name of Ampthill Clay. The place of the rock bed in the geological sequence is clear from its lithological character, its fossil contents, and its geographical distribution. In character it resembles almost exactly the basal beds of the Calcareous Grit at Stanton St. John. The fossils are extremely abundant, and include characteristic Lower Corallian forms. (See p. 42.)

The clay immediately below the escarpment of the rock is full of the *Gryphœa dilatata* which characterises the top beds of the Oxford Clay. Hence there is little doubt that the Arngrove, Studley and Boarstall stone is the dwarfed representative of the Lower Corallian. There are but few sections. The rock is generally broken up into small fragments by surface weathering, and is locally called "gravel." A large pit near New Arngrove Farm (one-third of a mile south-east of the Old Farm) formerly supplied road-metal for the district.

A quarter of a mile north of Studley Village, on the escarpment edge, there is a section by a pond showing 6 ft. of cherty sandstone with partings of clay.

A few other places where the same rock may be seen by the side of ponds may be enumerated without further description:—Studley Priory Park, close to the road. Road-side, half a mile north-east of Studley Village, opposite farm house. 200 yards south of same farm. Warren Farm. Common by New Arngrove Farm. Half a mile N.N.E. of New Arngrove Farm, near the road. One third of a mile W.N.W. of Boarstall Church. South of Decoy Pond, Boarstall. One third of a mile west of Gravelpit Farm. Holt's Farm. By moat south of Boarstall Tower. Half a mile south-east of Boarstall Church. Pasture Farm near Dane's Brook. South-west of Shabbington Wood. At Pasture Farm the rock is thrown down to the south-west by a small fault.

At all these places two or three feet of broken rock can be seen, the water in the ponds being held up by the Oxford Clay below.

On the east side of the outcrop of Calcareous Grit the ground is all clay up to the Portland Sands of Muswell and

Brill Hills. From Boarstall to the Thame the landscape is one of low relief, nowhere raised far above the streams which traverse it from north to south. Here and there slight ridges running approximately parallel with the outcrop form conspicuous features. They are probably caused by thin stone-beds in the clay which permit the outflow of water. The moist green pastures which prevail here present the strongest contrast to the wide arable tracts of the Corallian plateau.

As the clay at Boarstall follows with evident conformity the thin bed of Calcareous Grit, it occupies a position in the sequence of strata corresponding to higher beds of the Corallian formation. This is confirmed by an examination of its fossil contents. At the brick-pit of the Brill Brick and Tile Company, one mile north-east of Brill, there is the following section[1]:—

		Ft.
Kimeridge Clay	Blue clay with Saurian bones	12
	Pale cement-stone band	1
Ampthill Clay	Dark shaly clay with Belemnites, oyster beds and many crushed fossils	6

The following fossils were obtained by Mr. Woodward and Mr. Lamplugh[2]:—

From the cement-stone band and higher beds: *Plesiosaurus* (vertebra), *Pliosaurus* (vertebra), *Reineckia pseudomutabilis*? (De Lor), *Belemnites nitidus* Dollf., *Pleuromya recurva* (Phill.), *Pholadomya æqualis* J. de C. Sow.

From the Lower Beds: *Cardioceras excavatum* (J. Sow.), *Arca* sp., *Gryphœa dilatata* J. Sow., *Ostrea discoidea* (Seeley, M. S.) Kitchin, and *Serpula tetragona* J. de C. Sow.

Here there is a regular succession from the Kimeridge Clay downwards into clay containing forms characteristic of the Corallian Oolite, from which it is clear that while the coral banks so widely distributed in the Middle Oolitic formation were growing in the western region, many other life-forms flourished in the deeper waters where the accumulation of argillaceous sediment was continuous from the close of the Great Oolite period to that of the lower Portland Beds.

In the country between Boarstall and the Thame there are no sections, but the little oyster *Exogyra nana*, as before mentioned, may be easily found in the ploughed fields near the base of the formation, and has been invaluable in tracing the boundary. The upper boundary, however, is difficult to determine, and in the absence of sections on the west of Brill it has been necessary to use the succession in the brick-pit described above as a guide. Here the cement-stone band, which may be taken as a convenient line of division, forms a very marked feature at the base of the Kimeridge Clay slope, owing, probably, to the fact that it is the only pervious stratum within a considerable thickness of clay beds. The Kimeridge Clay stretches upwards 80 or 90 feet to the little

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[1] See also section by A. Morley Davies, *Quart. Journ. Geol. Soc.*, lxiii., 1907, p. 30, and *Proc. Geol. Assoc.*, xx., 185.

[2] These were identified in the Palæontological Department of the Geological Survey.

Portland outlier on Rids Hill, east of Brill. Applying these data to the west side, it is found that at about the same distance below the Portland Sands of Muswell Hill, there is a very marked feature where water oozes freely from the clay. There is evidently a water-bearing stratum, and though it may not be the cement-stone bed of Brill brick-pit, it is at nearly the same horizon. The foot of this slope has accordingly been taken as the boundary of the Ampthill and Kimeridge Clays. Further south the features become indistinct, and the thickness of the two clays, judging from their vertical and horizontal extent, is much reduced. This apparent irregularity may, however, be due to the greater inclination of the strata or to a small fault of which evidence could not be obtained. The physical features no longer serve as guide, owing probably to the inconstancy of the hard bands in the clay. The base of the Kimeridge Clay, west of Brill Hill, has perhaps been drawn too near the Portland outcrop, allowing too small a thickness for the formation; but this appeared the most natural position to draw the line judging by the nature of the ground.

In the cuttings for the new line of Great Western Railway, north and south of Rushbeds Wood, between Ashendon and Ludgarshall, north-east of Brill, about 25 feet of Ampthill Clay with bands of pale hard marl and argillaceous limestone, have been exposed. The lowest layers contained *Exogyra nana* and spines of *Cidaris*, as observed by Mr. Morley Davies.[1]

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[1] *Proc. Geol. Assoc.*, xx., p. 184.

CHAPTER V.

UPPER OOLITIC ROCKS.

BY H. B. WOODWARD, WITH NOTES BY T. I. POCOCK.

KIMERIDGE CLAY.

The Kimeridge Clay consists of dark grey and black shaly clay, with septaria, and much selenite in places. The clay weathers brown at the surface. The beds are as a rule darker, and in mass more shaly, than the Oxford Clay, and their thickness probably nowhere exceeds 100 feet in the area.

The Kimeridge Clay in general owes its dark tint partly to carbonaceous matter, partly to bisulphide of iron.[1] The decomposition of pyrites by atmospheric agents leads to the formation of selenite, lime being present in the clay itself as well as in the fossils. In some cases the Oyster shells (*O. deltoidea*) have been converted into sulphate of lime, as noted by Dr. Kidd at Shotover.[2] The decomposition of the pyrites leads to the formation of limonite, which, in the case of the Headington quarries near Shotover, is washed from the Kimeridge Clay on to the Corallian stone beneath.[3]

Mr. A. Morley Davies has drawn attention to the selenitization of belemnites from the brickyard at Rid's Hill, near Brill.[4]

The best section of Kimeridge Clay is exposed in Chawley brickyard at Cumnor Hurst, where it is overlaid by Lower Greensand, Gault, and Drift in upward succession. The beds are extremely irregular, no single part of the section showing the full thickness. The Greensand fills deep hollows in the Kimeridge Clay, and extends down the slopes of Hurst Hill with a dip amounting to 30° in one case. In its turn it is cut into to a depth of about 15 feet by Gault and Drift. (See p. 80.) The following table gives the approximate thickness of the different strata, the measurements of the Kimeridge Clay being those of Sir. J. Prestwich:—

		Ft.	in.
Drift ...	Bedded gravel of quartzite, flint, &c., with sand...	10	0
Gault	Dark bluish-grey clay with phosphatic nodules and fragments of the Ammonite *Hoplites interruptus*. (See p. 80.)	10	0
Lower Greensand	Coarse brown false-bedded quartzose sand with concretionary ironstone	20	0

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[1] G. Maw, *Quart. Journ. Geol. Soc.*, xxiv., p. 357 ; see also analysis by J. D. Kendall, *Trans. N. of Eng. Inst. of Mining Engineers*, xxxv., p. 156.

[2] "Outlines of Mineralogy," 1809, vol. i., p. 68.

[3] See Report of Excursion of Geologists' Association to Oxford, 1869, p. 6 (separately printed).

[4] *Quart. Journ. Geol. Soc.*, lxiii., 1907, p. 33.

		Ft.	in.
Kimeridge Clay	Pale grey sandy clay	2	0
	Dark bluish-grey slightly calcareous clay, with greenish sandy seams, nodules of earthy limestone, and large septaria with *Ammonites biplex** and lignite	18	0
	Clay, with band of fossils, yielding "*Plesiosaurus*," *Am. biplex*,* *Pleurotomaria reticulata*, *Astarte*, *Cardium striatulum*, *Lima*, *Modiola bipartita*, *Pleuromya recurva*, *Pecten nitescens*, *Perna mytiloides*, *Pinna lanceolata*, *Thracia depressa*, *Trigonia*, and *Serpula tetragona*	14	0
	Seam of clay laminated with white sand (Iguanodon-bed), with *Camptosaurus* [*Iguanodon*] *Prestwichi*, *Aptychus latus*, *Pleurotomaria*, *Astarte*, *Exogyra virgula* (abundant) *Trigonia*, *Lingula ovalis*	0	3
	Clay with large septaria, with *Dacosaurus*, *Ichthyosaurus*, *Pliosaurus*, *Astarte lineata*	4	0

* Probably *Holcostephanus pallasianus* (d'Orb.).

At Sandford, according to Mr. E. S. Cobbold, "a peculiar bright red earthy layer from 4 to 6 inches thick" occurred at the junction of the Kimeridge Clay with the Corallian Beds. From the clay he recorded vertebræ of *Pliosaurus*, good specimens of *Rhynchonella inconstans* and numerous crystals of selenite.[1]

Besides the well-known section at Chawley Brickyard there are few sections of Kimeridge Clay in the western part of the district. It was formerly worked for bricks in the small outlier west of Marcham, but the pit is now overgrown. It has been frequently pierced at Abingdon and Radley by wells sunk to the water-bearing Corallian Beds below, but for the most part this low-lying tract is covered by river-deposits. In pits on the south of Foxcombe Hill the clay can be seen underlying the iron-sand. T. I. P.

A boring at Baldon House, March Baldon, carried out in 1883, proved the following strata, as noted by J. H. Blake, from data communicated by Mr. Edward Margrett:—

		Thickness. Ft.	Depth. Ft.
[Portlandian]	Yellow clay and sand ... ... about	35	35
Kimeridge Clay	Dark grey clay... ... ... about	90	125
	Rock	1	126
	Grey clay	20	146
Corallian	Rock with veins of clay	20	166
	Rock with sand and numerous shell-fragments	15	181
	Fine white sand	14	195
	Rock	1	196

The following fossils were obtained and identified by Mr. E. T. Newton:—

From the depth of 40 *feet*—

Perisphinctes plicatilis (*J. Sow.*).
——— near to eupalus (*d'Orb.*).
Exogyra.
Protocardia striatula (*J. de C. Sow.*).
Serpula.

From the depth of 180 *feet*—

Exogyra nana (*J. Sow.*).
Pecten fibrosus *J. Sow.*
Glyphæa.
Fish vertebra.

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[1] *Quart. Journ. Geol. Soc.*, xxxvi., p. 318.

The following fossils[1] were lately collected for the Geological Survey by Mr. John Pringle, from excavations in the Kimeridge Clay near the Viaduct over the Thames immediately S. of Abingdon Junction :—

Arca longipunctata ? *Blake.*
Astarte ?
Exogyra virgula *Defr.*
Lucina ?
Protocardia striatula (*J. de C. Sow.*).
Aptychus sp.
Perispinctes rotundus ? (*J. Sow.*).

Shotover Hill.

The brickyards on the western side of Shotover Hill, near Headington, show the Kimeridge Clay resting on the Corallian rocks and overlain by Portland Beds. The thickness of the clay was estimated at 100 feet by Prof. Phillips, but only about 30 feet of it is exposed.

It consists of bluish-grey and dark blue shaly clay, weathering brown at the top, with lignite and with a few layers of septaria and much selenite. (See p. 34.) Prof. Phillips noted that about 15 feet from the base there is a septarian band yielding *Rhynchonella inconstans*, &c.; lower down there are layers of *Ostrea deltoidea*, and near the base *Thracia depressa* and *Exogyra virgula* are fairly abundant. At the base coprolites were first noticed by the Rev. H. Jelly.[2]

Sowerby figured *Ostrea deltoidea* from this locality, remarking that the fossils were known as "Heddington (Headington) Oysters."

In addition to various Saurian remains, the following fossils have been recorded from the Kimeridge Clay of Shotover Hill[3] :—

Asteracanthus ornatissimus.
Hybodus acutus.
Ischyodus Egertoni.
Lepidotus maximus.
Holcostephanus pallasianus ["Ammonites biplex"].
Belemnites abbreviatus var. excentricus.
Aptychus (Trigonellites).
Pleurotomaria reticulata.
Astarte ovata.
Exogyra virgula.
Ostrea deltoidea.
Thracia depressa.
Discina latissima.
Rhynchonella inconstans.
Serpula.

Prof. Phillips recorded *Belemnites* "*explanatus*" [*B. nitidus*] from the upper part of the Kimeridge Clay at Waterstock, near Thame, and Wheatley, near Oxford, as well as from the Hartwell Clay.[4]

The palatal teeth of fishes, more particularly those of *Lepidotus maximus* [=*Sphœrodus gigas*], from the Kimeridge Clay, were described by old writers as Bufonites or Toad-stones, and were utilized in former times as ornaments, or as charms.[5]

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[1] Numbered [Pr. 4009—4017] in the Geological Survey Collection.

[2] Buckland, *Trans. Geol. Soc.*, ser. 2. vol. iii., p. 232 ; see also Fitton, *ibid.*, vol. iv., p. 278 ; Phillips, Geol. Oxford, &c., pp. 329, 413, and *Quart. Journ. Geol. Soc.*, vol. xiv., p. 238 ; and Hull, Geol. parts of Oxfordshire and Berkshire, p. 10.

[3] See "Jurassic Rocks of Britain," v., p. 168.

[4] "British Belemnites," 1865, p. 128.

[5] H. Woodward, *Geol. Mag.*, 1893, p. 246.

The brick and tile works at the western end of Wheatley Village, where Kimeridge Clay was worked, have long been abandoned. There, according to J. H. Blake (1898), the section showed 30 to 50 feet of blackish grey clay and shale. In the collection of Mr. James Parker, of Oxford, there is a specimen of *Astarte hartwellensis* from this locality.

At the present time an extensive clay pit is worked for brickmaking on the south side of the railway, north-east of Littleworth by Wheatley. Here the following fossils were obtained[1]:—

Ichthyosaurus (vertebra).
Pliosaurus (vertebra).
Belemnites nitidus *Dollf.*
Holcostephanus cf. pallasianus (*d'Orb.*)
Perisphinctes.
Ostrea cf. duriuscula *Phill.*

Plot mentioned in 1677 that at "*Whately* Towns end, near the foot of the hill," some attempts had been made for coal.[2] H. B. W.

Mr. A. J. Jukes-Browne noted the following section at the brickyard by the side of the high road a mile north of Great Milton:—

		Ft.	in.
	Sandy soil	3	0
	Brown loamy sand ... ... from 0 to	8	0
Kimeridge Clay	Dark blue clay	6	0
	Grey argillaceous sand	3	0
	Hard blue sandy limestone	0	9
	Fine grey sand about 12 inches, becoming argillaceous and lilac-coloured and passing down into strong blue clay	7	0

[The brown loamy sand may belong to the Shotover Sands, or Portland Beds, or may be Drift.]

The blue clay contains Ammonites and Saurian bones, and at its base *Protocardia striatula, Pleuromya* sp., and *Exogyra* sp., the first two in phosphate like Potton fossils.

The limestone weathers very sandy, but contains large Ammonites and other fossils. A. J. J.-B.

Brill.

At the brickyard north-west of Brill, clays were formerly dug beneath the Portland stone-beds, and numerous iridescent fossils were obtained. The clays belong in part to Kimeridge Clay and in part to the Lower Portland Beds (Hartwell Clay). (See p. 60.)

Reference has been made to the brickyard of the Brill Brick and Tile Company on the eastern side of Brill (p. 44). It is outside the bounds of our area, and it will be sufficient to note that Mr. A. Morley Davies has recorded *Aptychus latus* (Park.), *Exogyra virgula* Defr., from the higher beds of clay above two bands of creamy limestone. From these bands he records some Ammonites of doubtful species, also *Pholadomya æqualis* J. de C. Sow., and *Pleuromya recurva* (Phil.).

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[1] Named in the Palæontological Department of the Geological Survey.

[2] Nat. Hist. of Oxfordshire, p. 57.

CHAPTER VI.

UPPER OOLITIC ROCKS—(*continued*).

PORTLAND BEDS.

BY H. B. WOODWARD, WITH NOTES BY H. H. THOMAS.

This group consists most largely of sandy strata, with beds of limestone as well as sand and thin clay-bands in the upper part. The conventional division into Portland Sand and (overlying) Portland Stone appears applicable only to portions of this area, and even then it is better to use the terms Lower and Upper Portland Beds,[1] as both divisions contain beds of sand, and in certain tracts the Lower beds pass into a loamy clay equivalent to the Hartwell Clay.

The Portland Beds are represented by one colour on the map; but generally from Shotover Hill to Great and Little Milton the Upper and Lower Beds have been separated by a line. This is not, however, of uniform stratigraphic value. The Hartwell Clay is coloured the same as the Kimeridge Clay.

In the area to the south and south-east of Oxford we find evidence of several outlying masses of Portland Beds, but it is not improbable that the rocks exposed at Great Milton are portions of a large mass continuous underground with those of Thame and Aylesbury.

Shotover Hill.

Shotover Hill, which lies to the east of Oxford, includes the commons of Cowley and Horsepath, and affords some famous sections of the Portland Beds. It is part of a straggling outlier stretching in a south-easterly direction to Garsington and Cuddesdon, and covered irregularly by two outliers of the Iron Sands.

The old coach road to London passed over the summit of Shotover Hill, and the several groups of strata opened up from near Headington at the western foot of the hill to the "Iron Sands" on the top, early attracted the attention of geologists. Especially noteworthy were the great "sand-ballers" or "giant's marbles" derived from the Portland Sands, some of these doggers being from three to six feet in diameter and two feet or more in thickness.

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[1] See "Jurassic Rocks of Britain" v., pp. 180, 181; and Green, Geol, Banbury, p. 46.

The following is the general section at the western end of Shotover Hill:—

Shotover Sands.

Portland Beds.
- Upper
  - Sands with hard ferruginous bands, *Trigonia*, 20 or 30 ft
  - Whitish limestones, large Portlandian fossils. *Cardium dissimile*, &c.
  - Clays, loam and greenish sands. } 4 ft.
  - Rubbly glauconitic limestone, *Pleurotomaria* cf. *rugata* Benett. } 4 ft.
  - Lydites.
  - Blue and brown clay, with lydites and phosphates in base of clay and top of sands, 3 to 5 ft.
- Lower
  - Yellow and greenish sands, slightly glauconitic, with "sand-ballers," huge spheroidal doggers of calciferous sandstone, blue-hearted, and with small lydites, *Perisphinctes plicatilis* ? (J. Sow.), *Exogyra* sp., *Lima*, *Lithodomus* sp., *Perna* cf. *mytiloides* Lam., *Pholadomya*, *Trigonia*, &c., 20 ft.

The full thickness of the lower sandy division is probably about 60 feet, while the overlying division may be from 40 to 50 feet. The total thickness of the Portland Beds at Shotover is probably rather more than 100 feet[1]; but it is nowhere possible to measure the full thicknesses of all the subdivisions.

The upper beds of Shotover yield the following fossils:—

Perisphinctes boloniensis (*de Lor.*)
Cerithium portlandicum *J. de C. Sow.*
Natica elegans *J. de C. Sow.*
Cardium dissimile *J. de C. Sow.*
Lucina portlandica *J. de C. Sow.*
Ostrea expansa *J. Sow.*
Pecten (Amusium) lamellosus *J. Sow.*
Trigonia gibbosa *J. Sow.*

Among fossils from the lower beds the following have been recorded[2]:—

Perisphinctes pectinatus *Phil.*
Pecten nitescens *Phil.*
Perna.
Pholadomya tumida *Ag.*
Pinna.
Trigonia pellati *de Lor.*

Fitton described the top layer as a "very hard brown sandstone, with a few *Trigoniæ*," and this was probably the bed from which Dr. Teall long ago obtained a specimen of *Trigonia gibbosa* var. *damoniana*[3]: a form now spoken of simply as *Trigonia damoniana* de Lor. The suggestion made with reference to the horizon of the fossil receives confirmation from the researches of Mr. Lamplugh. (See p. 68.)

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[1] See also A. M. Davies, *Proc. Geol. Assoc.*, xvi., 27.

[2] Phillips, *Quart. Journ. Geol. Soc.*, xiv., p. 238, and Geology of Oxford, &c., pp. 326, 413, 421; see also Hull, Geol. parts of Oxfordshire and Berkshire, p. 12; and J. F. Blake, *Quart. Journ. Geol. Soc.*, xxxvi., p. 213, and Plate VIII.

[3] Fitton, *Trans. Geol. Soc.*, ser. 2, iv., pp. 275, 278; Teall, "Potton and Wicken, Phosphatic Deposits," pp. 32, &c., 1875; H. B. Woodward, "Jurassic Rocks of Britain," vol. v., p. 218.

More recently Mr. John Pringle has collected (for the Geological Survey) the following Portlandian fossils from the western end of Shotover Hill:—

Upper Pit, in ferruginous sandstones. [Pr. 3985-3988.]

Lucina portlandica *J. de C. Sow.*
Modiola boloniensis ? *(de Lor.)*
Trigonia damoniana ? *de Lor.*

Lower Pit, in sands with great doggers. [Pr. 3953-3977.]

Perisphinctes giganteus ? *(J. Sow.)*
Area cf. catalaunica *de Lor.*
,, cf. rhomboidalis Contej.
„ sp.
cf. Astarte rugosa, (*J. de C. Sow.*)
Corbicella ?
Exogyra bruntrutana ? (Thurm.)
Lucina portlandica *J. de C. Sow.*
Ostrea expansa *J. Sow.*
„ sp.
Pecten cf. morini *de Lor.*
Pecten sp.
Perna mytiloides *Lam.*
Pholadomya rustica *Phill.*
cf. Placunopsis lycetti *de Lor.*
Pleuromya tellina *Ag.*
,, sp.
Protocardia morinica *(de Lor.)*
„ cf. morinica *(de Lor.)*
Trigonia muricata ? *(Goldf.)*
„ sp.
Serpula sp.

In the course of observations on the fauna of the Shotover Sands, Mr. Lamplugh saw reason to discriminate between the ironstone-beds with freshwater fossils, and those with marine forms; the latter (as elsewhere mentioned) proving on Shotover Hill to be truly Portlandian.[1] From the rock-specimens gathered by him the following notes have been drawn up.

METASOMATIC CHANGES IN THE PORTLAND STONE OF SHOTOVER.

By H. H. Thomas, M.A., B.Sc.

The normal Portland Stone is in general a shelly and oolitic limestone, fairly pure in composition; but under the influence of percolating waters it has locally undergone extensive changes. The most usual change is that of partial, or more or less complete, silicification, but in many cases much of the calcium carbonate has been replaced by ferruginous compounds. In the latter case, as mentioned above, this change has caused the altered Portland Stone to be confused with the freshwater ironstone of a higher horizon. In the neighbourhood of Shotover Hill remnants of the Portland Stone are met with which have been all more or less changed from their original character by the process of silicification. On the south side of the hill a rock occurs which, under the microscope, is seen to be made up of closely packed oolitic grains set in a matrix which is almost wholly silicified. The oolitic grains themselves show all stages from partial to complete silicification, but in some of the specimens which are less changed they still consist in part of carbonate, and retain their original concentric structure.[2] At the same time, in the more completely silicified rock, the outline of the grains is still distinct, being emphasised by dusty iron ores. The change in the oolitic grains seems to have taken place in two ways, both by the replacement of the calcite by chalcedonic silica, and by the growth of quartz, probably on minute clastic grains of that mineral which formed the nuclei of the oolitic structures. The quartz has grown in perfect optical continuity, but not in such a manner as to show crystal outline, the result being an irregularly-shaped mass which often entirely or only partially encloses the oolitic grain. At the same time the original outline of the oolitic structure may be traced through the quartz by means of the ferruginous inclusions.

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[1] *Rep. Brit. Assoc.* for 1904 (Cambridge), p. 548.
[2] See also "Jurassic Rocks of Britain," v., pp. 186, 187.

Other examples of the Portland Stone, such as those from a sand-pit east of the western brickyard, show that nearly all the oolitic grains in these cases have been replaced by crystalline quartz, with irregular or subrounded outline. That this silicification has proceeded from the centre is shown by the fact that many of the oolitic grains are not completely replaced, the outer margin, or part of it, being still formed of carbonates.

From the above considerations it is obvious that all the larger quartz grains in these silicified oolites are of secondary and not of clastic origin.

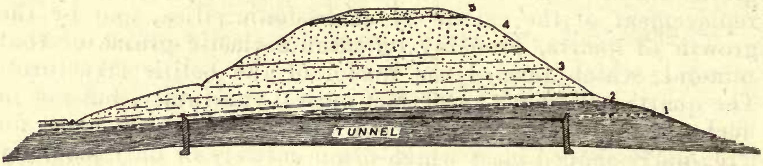
Occasionally the rock is highly ferruginous, and then it is seen that the iron was introduced, as was the silica, from without, and it is evident that those parts only which had not been previously silicified, both of the matrix and of the oolitic grains, have been replaced by iron oxides: probably originally deposited as carbonate. It is assumed, therefore, that the iron-bearing waters followed those carrying silica. In some examples it seems that most of oolitic grains had clastic quartz nuclei, and therefore there was a tendency to the formation of quartz rather than of chalcedonic material.

In the rocks collected from a sand-pit on the eastern side of the reservoir, most of the oolitic grains are replaced by masses of secondary quartz, and these are set in a matrix consisting chiefly of iron oxide, causing the rock to present all the appearance of a ferruginous grit. It is evident that in this case we are dealing with a rock which, without regard to less changed specimens, would have been classed as original in character, whereas in reality all its components are of secondary origin.

It is suggested that other so-called ferruginous grits may prove to have had their origin in limestones. H. H. T.

During the construction of the railway through the hill between Horsepath and Wheatley, a section of the strata passed through was drawn by Mr. Thomas Codrington. A copy of this is here given (Fig. 7). Two bands of stone, 4 feet apart and 1½ to 2 feet thick, generally very hard, were constant throughout the cutting, dipping 1 in 110 or ½° N.N.W. These were full of fossils, and the upper layer was in parts loose sandstone passing into compact limestone.

FIG. 7.—*Section along line of railway between Horsepath and Wheatley.* (*T. Codrington.*)



5. Shotover Sands.	
4. Yellow sand Limestone Clay	Upper Portland Beds.
3. Sandy and clayey beds 2. Two layers of sand-rock	Lower Portland Beds.
1. Strong clay	Kimeridge Clay.

The Lower Portlandian Beds (3) were noted by Mr. Codrington as "dark sandy clay"; they are continuous with the sands with great doggers of the Shotover section. It is to be remembered, however, that these Lower Portland Beds are represented by loamy clays at Brill, and in the intermediate area at Red Hill, Forest Hill; strata that represent the Hartwell Clay of Aylesbury, but have not been separated from the Kimeridge Clay on the Geological Survey map.

Springs are thrown out by the Kimeridge Clay at various places around the Portland outliers, and other springs are thrown out by the clay-band in the Portland Beds.

To the north-east of Hill Farm, Horsepath, there is a spring thrown out by the clay in the Portland Beds. Above these are yellowish or orange sands, and ferruginous stones are thrown out of the rabbit-burrows. Here were found *Trigonia damoniana* (de Lor), and other fossils, also cherty rock and whitish loamy sand.

The following record of a well dug in 1893 in Horsepath Parish, by the Windmill, south-west of Wheatley, was noted by J. H. Blake (1897):—

		Thickness.		Depth.	
		Ft.	in.	Ft.	in.
Shotover Sands	Brown sandy soil	3	0	3	0
	White and iron-stained sand ...	14	9	17	9
Portland Beds	Red sand with black pebbles (size of hazel nuts)	1	3	19	0
	Seam of yellow pipe-clay	0	3	19	3
	Nodules of ironstone	0	6	19	9
	Hard white stone	6	0	25	9
	Iron-ore	1	0	26	9
	Greensand (similar to that used for moulding purposes)... ...	10	11	37	8
	Hard grey stone	1	6	39	2
	Greensand with hard concretionary masses of stone 1 ft. by 1½ ft.	10	0	49	2
	Hard rock—the upper 4 feet very hard; the lower part softer, with concretionary masses, very fossiliferous, *Trigonia*, &c. Water	6	11	56	1
[Kimeridge Clay?]	Reddish-brown clayey loam ...	2	10	58	11

The presumed overlap of the Shotover Sands on to the Kimeridge Clay shown on the old Geological Survey map at Littleworth, near

Wheatley, was ascertained by Mr. J. H. Blake in 1897 to be erroneous, the prolongation of the outlier being due perhaps to the occurrence on the north of the old Wheatley and Shotover road of "a patch of chocolate coloured sand with ironstone, overlying Kimeridge Clay." As Mr. Blake remarked: "This is in all probability drifted material; but had it been of the same age as that on the high ground—to which it has a very similar appearance on the surface of the field—it ought to have been shown as an outlier, not connected."[1]

A similar downwash of sand, probably Portlandian, occurs on the hill one quarter of a mile north-west of Shotover House.

Forest Hill.

The outlier of Red Hill by Forest Hill was originally mapped as "Lower Greensand" on Kimeridge Clay; but during the re-survey traces of Portland Beds were proved to occur. Their presence at the new Cemetery and on the eastern side of Red Hill was inferred in 1904; and definite evidence was subsequently obtained in a trench made during building-operations for Mr. W. C. Tyndale, where a fragment of a large Ammonite was found. The section on the hill was as follows:—

Shotover Sands	Red ironstone	5 or 6 feet.
	White and brown sands and occasional ironstone	6 feet.
Portland Beds	Glauconitic limestone with *Holcostephanus* cf. *pallasianus* (d'Orb.).	

The ironstone is probably faulted in the central part of the hill, as the strata at the south-eastern end are on a level distinctly lower than those of the north-western portion of the hill.

At the spring south-west of the semi-circular plantation on Red Hill, soft mealy sands and loams were exposed—here probably faulted against the Kimeridge Clay.

Cuddesdon and Garsington.

North-east of Cuddesdon Palace a small quarry showed the following section:—

	Irregular pipes of brown loam and sand.	
Portland Beds	Oolitic and tufaceous-looking rock, crumbly, with *Natica* sp., also *Trigonia incurva*? (Benett) at top. The beds are stained in places by pockets of overlying ironsand ...	1 or 2 feet.
	Pale oolite, more or less shelly, with *Ostrea*; used for building-purposes	10 feet.

The upper bed here would appear to correspond in character with the "Malm" above the Portland Stone at Garsington, that was referred to the Purbeck Beds by Fitton.[2] The above-mentioned fossils, however, indicate that the bed is Portlandian.

In Fitton's time the principal stone-pits at Garsington were "in the western escarpment of the hill north of the village, overlooking the low ground about Langcomb and Cowley"; Langcomb being probably the valley between Easington and Horsepath.

Prof. Hull noted a section, one mile north of Garsington, showing white oolitic limestone (Portland Beds) overlaid irregularly by the Shotover Sands.[3] The limestone was much eroded at the upper surface, and contained *Trigonia*, *Pinna*, *Ostrea expansa*, &c.

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[1] Letter to H. B. Woodward, dated Oxford, November 30th, 1898.

[2] *Trans. Geol. Soc.*, ser. 2, iv., p. 277.

[3] Geology of parts of Oxfordshire and Berkshire, p. 11.

Mr. Morley Davies has also noticed that the Portland Beds to the north-west of Garsington near the "Red Lion" comprise[1]:—

		Ft.	in.
Yellowish and bluish green sand	about	16	0
Shelly sands passing into sandy limestone	...	1	0
More massive limestone	...	3	6

These beds appeared to him to occur but little above the Kimeridge Clay, but the evidence was not clear, and in some respects the strata compare better with the Upper Portland Beds. About half a mile to the north-east he observed in a trench the basal Portland Sands about 35 feet thick, capped by the "lydite bed," which he found to consist of black pebbles, mostly of chert, but including spherulitic felsite and phosphatised bone. Above this pebbly layer there was about 12 feet of glauconitic limestone (pebbly at base), with *Cardium dissimile;* then 9 feet of sand, with thin course of stone, and traces of higher limestone beneath the Shotover Ironsands.

Toot Baldon.

The possible occurrence of Portlandian strata at Toot Baldon was first suggested by John Phillips.

Thus in his notes on the section at Culham brickyard to the south-west of Nuneham Courtenay, and beyond the limits of our map, Phillips described a bed of green sand, 9 feet thick, below the Lower Greensand and Gault, and above the Kimeridge Clay, from which there were evidences of "an easy passage upwards from clay to sand." He obtained from this sand a few examples of the Ammonite like *A. polyplocus, Cardium striatulum, Thracia depressa, Pecten arcuatus, Corbula,* and wood; and he suggested that the bed might be "perhaps the first stage of a change towards the Portland series."[2]

At a later date, when the first Geological Survey was in progress by Prof. Hull, some fossils were found in "the road-cutting at Toot Baldon," during a tour of inspection with Prof. Ramsay and Mr. Etheridge. The discovery is thus mentioned:[3]

"At this place marine shells (*Ammonites Deshayesi* and *Terebratula sella)* of the Lower Greensand period were found, which are extremely valuable in determining the condition under which these beds were deposited."

The specimens are not in the Museum of Practical Geology, and they appear not to have been preserved. This is unfortunate, as subsequent observations have rendered most doubtful the identifications of the species.

When Phillips afterwards re-examined the place he stated his results as follows[4]:—

"Here [at Toot Baldon], some years since, on the very summit I found sandy and stony beds in small quantity and not well exposed. They yielded me no fossils; but my friends of the Geological Survey have since visited the locality, and obtained an Ammonite which they believed to be of the group of *A. Deshayesi* [on the authority of R. Etheridge]. I lately re-examined the spot, now less exposed than ever, without finding anything satisfactory. But on proceeding down the sloping road to the eastward, I perceived the clay to be there also covered by ferruginous bands, and commenced a persevering search for fossils. I made a considerable excavation, and obtained several shells, especially a *Mya*, *Pecten*, *Cardium*, *Trochus*, and an Ammonite which appears to be of the group of *A. polyplocus*, *A. triplicatus*, and *A. giganteus*. The mass is sand and sandstone with small black pebbles, and stained very brown by oxide of iron. It rests immediately on the Kimmeridge Clay, probably on the very top or upper layers." In the concluding paragraph of the same paper, Phillips adds . . . . . "the Geological Survey has had only a glance at an Ammonite, which was supposed to be *A. Deshayesi*, on the summit of a hill near Oxford, from which I obtained quite a different Ammonite, apparently of an Oolitic group, with other shells not sufficient to authorize the adoption of their sandy matrix into the Cretaceous family."

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[1] *Proc. Geol. Assoc.*, xvi., 19.

[2] *Quart. Journ. Geol. Soc.* xvi., 1860, p. 310; see also H. B. Woodward, "Jurassic Rocks of Britain," vol. v. pp. 167, 169, 217.

[3] The Geology of parts of Oxfordshire and Berkshire, *Mem. Geol. Survey*, 1861, p. 15.

[4] *Quart. Journ. Geol. Soc.* xvi., p. 311; and H. B. Woodward, "Jurassic Rocks of Britain," vol. v., p. 217.

In his later "Geology of Oxford" (p. 426), however, Phillips classed the sandy beds of Toot Baldon with the Lower Cretaceous.

Some further specimens were obtained during the re-survey by our colleague the late J. H. Blake, who while mapping this area found some blocks of more or less cherty sandstone with casts of fossils, in a field 700 yards east of March Baldon Green. The fossils were poorly preserved, but they were examined in the Palæontological Department of the Survey by Mr. E. T. Newton, who reported that:

> "Although the specimens can scarcely be taken to prove the strata to be of Lower Greensand age, yet their general facies points to this conclusion."[1]

It was noted by Mr. Lamplugh with regard to these specimens, that the cherty blocks since found on the slopes of Shotover Hill prove to be altered Portlandian rocks, as already described (p. 52); and that cherty beds are not known to occur elsewhere in the Lower Greensand of this district.[2] Therefore, in view of the unsatisfactory nature of the palæontological evidence, the question as to the age of the sandy deposits which directly overlie the Kimeridge Clay around Toot Baldon and March Baldon, was held by him to be an open question.

It should, however, be mentioned that during his examination of the strata between Culham and Toot Baldon, Mr. Lamplugh had observed a change in the lithological character and colour of the beds northwards from the neighbourhood of March Baldon. There they consist of buff or greyish sands of finer grain than the coarse and pebbly Lower Greensand of Culham and Clifton Hampden, and of great portion of Nuneham Park.

Meanwhile the Lower Cretaceous strata in this area had been described in 1898 as the "Toot Baldon Beds," by Mr. A. Morley Davies; although he admitted the possibility that there might be a trace of the lower sandy beds of the Portlandian at Toot Baldon.[3]

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[1] Summary of Progress, *Mem. Geol. Survey*, for 1900, p. 120. The specimens referred to are not preserved in the Survey collection.

[2] The cherty layers mentioned as occurring in the Shotover Iron-sand and Ochre Series (see Phillips, Geol. Oxford, pp. 414, 415) were evidently at the base of the series and probably Portlandian.

[3] *Proc. Geol. Assoc.*, vol. xvi., p 45.

During the early part of the year 1907 Mr. Davies very kindly sent to the Museum at Jermyn Street, for determination, some fossils which he had collected in 1903 from sandy strata in the lane-cutting south of Oldhouse Farm, Toot Baldon. The specimens include a clavellate form of *Trigonia* not sufficiently perfect to be identified specifically; also *Cyprina?*, *Exogyra thurmanni?* (Etallon), and *Protocardia?* As the evidence supplied by these fossils was not regarded as conclusive, it was decided that Mr. John Pringle should visit the area; and although he was unsuccessful at the locality where Mr. Davies obtained his specimens, other fossils of identical matrix were obtained in the neighbourhood, some of them of similar species to those found by him in the Lower Portland Beds at Shotover Hill (see p. 52), and likewise preserved in rock of similar lithological character. Mr. Pringle ascertained that in the fields east of March Baldon and at Baldon Row, highly fossiliferous "doggers" of sandstone are frequently met with at a depth of 6 to 8 feet from the surface. He further noted that the sands with Portlandian fossils are fine-grained and quite distinct from those of the Lower Greensand; thus confirming the suggestions made by Mr. Lamplugh. A line separating the Portland Beds and Lower Greensand has consequently been drawn on the map, in accordance with the evidence that could be gathered of the distribution of the different sandy deposits between the definite areas of Lower Greensand on the south, and of Portland Beds on the north.

The following fossils were collected from the Portlandian Beds by Mr. Pringle:—

Garden of house 400 yds. W.S.W. of St. Lawrence Church, Toot Baldon. [Pr. 3978-3984].

Astarte rugosa ? *(J. de C. Sow.)*
Corbicella ?
cf. Lucina portlandica *J. de C. Sow.*
Pecten cf. morini *de Lor.*

Field 900 yds. N.E. of Post Office, March Baldon. [Pr. 3989-4000]. (Portlandian).

Astarte rugosa *(J. de C. Sow.)*
Cyprina ?
Leda ?
Ostrea sp.
Pecten morini *de Lor.*
,, nitescens *Phill.*
,, sp.
Perna sp.

It should be mentioned that Mr. Pringle noted the strong resemblance of the sandy Portland bed seen at the southern end of the Culham pit, and previously mentioned, to the material composing the doggers of Portlandian sandstone met with at Toot Baldon; and he obtained from the Culham sand-bed a doubtful *Serpula* and a specimen near to *Isodonta longior* Blake.[1]

Great Milton and Great Haseley.

A mass of Portland strata appears from beneath the covering of Cretaceous rocks at Great and Little Milton, and the stone-beds have been worked below those rocks at Great Haseley and near Great Milton.

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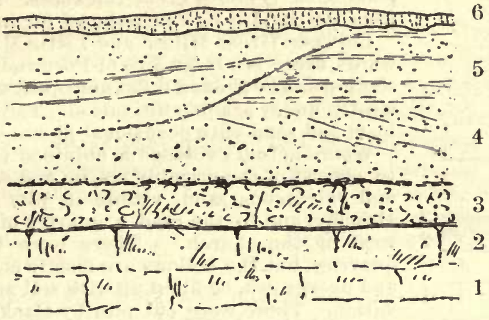
[1] These fossils [Pr. 4004-4007] are preserved in the Museum at Jermyn Street.

In a quarry on the eastern side of Great Milton the following beds were to be seen in 1886 (see also p. 72):—

FIG. 8.—*Section at Great Milton.*



		Ft.	in.
Shotover Sands.	6. Brown loam (used for brickmaking) up to ...	4	0
	5. Sand with bands of white and ochreous clay, with lignite	3 0 to 6	0
	4. Buff and white false-bedded sand with ferruginous layers and concretions; and at base, lydite pebbles and ironstone	3 0 to 6	0
Portland Beds.	3. Rubbly bed of sand with hard nodular calcareous sandstone and chert; *Ostrea expansa.* This had the appearance of a remanié bed	3 0 to 4	0
	2. Clayey and shelly layer with hard nodules ...	0	6
	1. Hard and soft calcareous sandstone (freestone), cherty in places, passing down into grey and greenish sandy oolitic limestone (burnt for lime); with *Ostrea, Perna, Trigonia gibbosa*: seen to depth of	6	0

From the workable stone-beds in this district Prof. Blake recorded:—

Lima rustica.
Ostrea expansa.
Pecten lamellosus.
Pleuromya tellina.
Trigonia gibbosa.
————incurva.

From the higher rubbly beds he obtained *Cerithium portlandicum, Perna,* &c. In these layers some of the lumps had "the appearance of rolled masses of stone, so consolidated by similar material that the separate pieces are scarcely recognizable."[1]

The following section at Great Haseley (Fig. 9) was noted in the old pit on the north of the village, near the school house:—

		Ft.	in.
Shotover Sands	5. Ironstone	4	0
	4. Ochreous and white clays, with bands of ironstone and ferruginous sand; more sandy towards base and false-bedded	15	0
	3. Laminated clay and ironstone	0	8
Portland Beds	2. Fine mealy calcareous sand	0	6
	1. Shelly earthy and sandy oolitic limestone: *Trigonia,* &c.	3	0

The top-beds for a depth of 5 or 6 feet were contorted and nipped up. Prof. Hull noted the presence of small pebbles of lydian stone in sandy oolite, which rested on 2 feet of white sand. Above the oolite there was then exposed 5 feet of chalky limestone, with *Ostrea expansa,* &c. This bed, he observed, was sometimes eroded.[2] It is the layer called "Curl" by Fitton. (See p. 73.)

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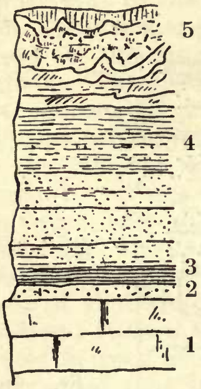
[1] *Quart. Journ. Geol. Soc.*, xxxvi., p. 214.

[2] Geol. parts of Oxfordshire and Berks, p. 11; See also Fitton, *Trans. Geol. Soc.*, ser. 2, iv., p. 276; and J. F. Blake, *Quart. Journ Geol. Soc.*, xxxvi., p 213.

FIG. 9.—*Section at Great Haseley.* (For references see p. 59



I was informed that all the best stone at Haseley had been worked out. The beds are very variable and the good stone is not of great thickness. Portland Stone from Portland is now introduced for tombstones, &c.

Between Great Milton and Little Milton, and eastwards, there is a large area of Portland Beds with few sections. The ground is flat and open, with large fields mostly under arable cultivation. The soil is a brown loam and sand with occasional pieces of limestone.

Where actual evidence is obtained the rock is seen to consist of the crumbly oolitic and sandy limestone and calcareous sand, visible in pits east of Great Haseley, and by the road a quarter of a mile south-west of the church.[1] There were formerly many quarries, but the hollows are mostly covered with soil and overgrown, or filled up with soil and under cultivation. There were old pits by Canker Leaze, west of Little Haseley, and by the plantation to the north. Other pits with much sand and decomposed stone are to be found north-east of Little Milton, some used as receptacles for dust and rubbish, and thereby liable to pollute the underground water.

East of Haseley Court, on the left bank of Haseley Brook, between Peg's Farm and Upper Standhill, there is a series of old pits that were opened up in Portland Stone and Sands. A well at Haseley Court was excavated in stone-beds.

Brill.

In the outlier at Brill the boundary drawn at the base of Portland Beds is in reality at the junction of the Upper Portlandian and the Hartwell Clay (Lower Portlandian), which merges downwards into the Kimeridge Clay. No practical purpose would have been served by attempting to discriminate the Hartwell Clay. The junction thus taken is marked by the outflow of numerous springs, which issue at the base of the glauconitic limestones with *Cardium dissimile, Perna,* and other Portlandian fossils.

At the old brickyard, west of Springfield Farm, and in an adjoining quarry on the north-western side of the hill, the following beds were exposed:—

		Ft.	in.
Upper Portland Beds	Oolitic and shelly limestone and marl with *Ostrea expansa* J. Sow., *Trigonia*	3	0
	Chalky rock, with Ammonites, *Lucina portlandica, Trigonia*	4	0
	Brown clay, with *Ostrea*	0	6
	Oolitic earthy rock	1	0
	Yellow sand, dark glauconitic sand and marly beds: *Pecten lamellosus* ... ... Glauconitic marly limestone, becoming sandy in lower part: *Cardium dissimile* J. de C. Sow., *Perisphinctes giganteus, Trigonia, Ostrea, Serpula tricarinata*? J. de C. Sow. Nests of green sand in places	about 7 0 or 8	0
	Lydite bed: brown clay with pebbles	1	0

See also A. Morley Davies *Proc. Geol. Assoc.*, xvi., p. 30.

		Ft.	in.
Lower Portland Beds passing down into Kimeridge Clay	Brown and greenish mealy sand	3	0
	Sandy clay, passing down into stiff blue clay, with iridescent Ammonites, *Thracia*, *Perna*, *Astarte hartwellensis*.	20	0

This section agrees in the main points with that recorded by Fitton,[1] who enumerates a number of fossils.

The pits were visited by the Geologists' Association under the guidance of Prof. J. F. Blake in 1893, and he then recorded from the fossiliferous glauconitic bed the following fossils[2]:—

Holcostephanus "biplex."
Perisphinctes boloniensis.
Cardium Pellati.
Lima rustica.
Mytilus boloniensis.
Pecten lamellosus.
Perna Bouchardi.
Pleuromya tellina.
Trigonia muricata.
——— Pellati.

At the base of the Portland stone-beds on Muswell Hill, as at Brill, there is a similar glauconitic limestone with *Cardium dissimile*, &c., beneath which copious springs are thrown out at various points around these outliers.

PURBECK BEDS.

BY G. W. LAMPLUGH.

Shotover Hill.

There is no evidence of Purbeck Beds on the main portion of Shotover Hill, but in the south-eastern portion of the Portlandian outlier traces of Purbeck Beds were noted here and there by Fitton.[3] Thus above the Portland Stone at Combe Wood, south of Wheatley, he observed beds like the "Malm" of Garsington. They consisted of compact and oolitic limestone and rubble, and yielded remains of *Cypris*, *Mytilus*, *Modiola*, *Paludina elongata* and *Planorbis?* They are overlain by the Shotover Beds.

The following section of a stone-pit at Garsington is here abbreviated from that recorded by Fitton[4]:—

		Ft.	in.
	Loamy soil	2	0
[Shotover Sands]	Ferruginous brown sand and greenish sand, with yellow ochre and fuller's earth	8	0
[Purbeck Beds]	*Malm*, soft limestone, and softer marl, much decomposed; comprising:— *a.* Light greenish-grey marl with,in the upper part. detached fragments of silicified coniferous wood, like that of Portland, and portions of bone; *b.* Limestone, with some oolitic grains; *Paludina*, *Planorbis?* *Mytilus*, and *Cypris*; *c.* Limestone, in some places like the "Pendle" of the pits at Whitchurch, oolitic and botryoidal in places, with *Paludina*, &c.	4	
Portland Stone			

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[1] *Trans. Geol. Soc.*, ser. 2, iv., pp. 280, 283, 299; see also Whitaker, in Geol. Banbury, pp. 47–49; J. Mitchell, *Proc. Geol. Soc.*, ii., p. 6.

[2] J. F. Blake, *Proc. Geol. Assoc.*, xiii., p. 73; *Quart. Journ. Geol. Soc.*, xxxvi., pp. 209, 226, &c.; see also H. B. Woodward, "Jurassic Rocks of Britain," v., p. 222.

[3] *Trans. Geol. Soc.*, ser. 2, iv., pp. 272, 275.

[4] *Ibid.*, ser. 2, iv p., 277.

Brill.

The presence of Purbeck Beds beneath the Ironsands of the Brill outlier was first definitely recognised by the Rev. P. B. Brodie, in 1867,[1] though one of the sections (C) at Brill, published by Fitton in 1836,[2] includes the strata since found to belong to the Purbeck series. Phillips,[3] in 1871, gave the following generalized section of the series:—

	Ft.	in.
White calcareous laminated band, marly and stony	1	0
Grey argillaceous beds	3	0
White calcareous, marly or stony [bed]	2	0
Grey clay	0	6
White laminated stone	1	0
Grey clay	1	0
White stone	1	0
Grey clay	0	6
	10	0

It is possible, however, that the thickness is here over-estimated, as the sections on the lower slope of Brill Common, in which these beds are exposed, are much obscured by slips, which tend to duplicate the strata. The present exposures seem to indicate a total thickness of not more than five or six feet; but as the series is evidently very variable both in composition and thickness, it may have been locally thicker in the excavated part of the Common than in the places where it still remains.

The best exposure when the ground was surveyed (in 1904) was in a small stone-pit, close to the west side of the high road that runs along the eastern margin of Brill Common, 300 yards north of Temple Farm. The beds were much slipped, and were also disturbed by previous workings, but the section appeared to be as follows[4]:—

		Ft.	in
	Top soil, &c....	1 0 to 2	0
Shotover Sands	Pale grey clay, with a pimply structure suggestive of ostracoda, and with bits of plants: much slickensided and brecciated by slipping ... ... about	1	0
	White and buff fine sand and pale grey clay, with crushed remnants of ironstone concretions: irregularly mixed and confused	3 0 to 4	0
	Yellow and pale buff fine sand and sand-rock with ironstone concretions at base	1	0
Purbeck Beds	Tough bright-green clay with rusty spots, with some earthy fragments and ironstone concretions: much crushed: called "peter" by the quarrymen	0 6 to 0	9
	Brecciated white stone and marl, with broken lumps of hard calcareous grit ("pitching-stone" of the quarrymen) at the top, and Portland limestone below: all crushed and mixed by slipping ... ... seen for	3	0

The quarrymen state that the "pitching-stone" (which is dug for road-metal) occurs in two irregular beds,[4] with a parting of sandy loam between, the lower and thicker bed averaging 6 inches in thickness. From the heap of this "pitching-stone" at the entrance to the quarry some obscure and indeterminable fossils were obtained, apparently fragments of marine lamellibranchs.

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[1] *Quart. Journ. Geol. Soc.*, vol. xxiii., pp. 197–199.
[2] *Trans. Geol. Soc.*, ser. 2, vol. iv., pp. 280–281.
[3] Geology of Oxford, &c., p. 418.
[4] Compare Fitton's section, *op. cit.*, p. 281.

Traces of the bright-green clay that is regarded as the topmost bed of the Purbeck in the above section, were also visible in the deep sand-pit at the more northerly windmill on Brill Common; and there appears to be a trace of the lower part of the series at the top of the quarry in Portland limestone, 80 yards distant, at the northern edge of the Common.

In an old pit, 450 yards further south, on the slope below the Congregational Chapel, a much-obscured section revealed Purbeck Beds of a different type, consisting of 3 or 4 inches of tough black earth or clay, suggestive of an ancient surface-soil, resting on 4 to 6 inches of tough dark-grey earthy material speckled with small bits of a paler material like decomposed white stone. A peculiar earthy breccia of similar character to the latter bed, but much thicker and coarser, forms part of the Purbeck Beds exposed in the well-known "Bugle" Pit at Hartwell[1]; and similar material has also been recently exposed in a railway-cutting on the Great Central line, ¼ mile west of Haddenham. In the Brill section, thin shell-fragments were abundant both in the earthy breccia and in the tough black clay above it, but were not sufficiently well-preserved for identification.

It is only in the above-described sections of Brill Common that the Purbeck Beds are traceable, and they are consequently indicated on the map only in this quarter. Traces of greenish clay above the Portland Stone were observed by Mr. Woodward to the east of Brill Church, on the scarp below Hampden House. Whether the series is prolonged northward into the Muswell Hill outlier, and southward beyond Brill, is very doubtful; for although beds so thin might be readily hidden by downwash on the steep slopes in which their outcrop would occur, it is just as probable, from their general structure, that they were originally impersistent, and, moreover, that they have been partly cut away by the stronger current that deposited the Ironsands. The fossils indicate that the series is of estuarine origin, marking the transition from the purely marine conditions of Portlandian times to the fresh-water conditions indicated by the Ironsands (Shotover Sands).

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[1] [This rubbly bed at Hartwell "appeared to me to belong to the Drift" when I examined the section prior to the publication of the Memoir on Jurassic Rocks (see vol. v., pp. 224, 279). The bed was then exposed only at the surface; it has since been cut back so as to expose higher beds of Purbeck strata above it, and its position in that formation is no longer to be doubted.—H. B. W.]

CHAPTER VII.

LOWER CRETACEOUS.

BY G. W. LAMPLUGH.

SHOTOVER SANDS.

The Brill and Muswell Hill Outliers.

The Upper Jurassic rocks in the extreme north-eastern corner of the area, are capped by two isolated patches or outliers of sand, with subordinate bands of clay, to which the general term of "Ironsands" has been usually applied on account of the prevalence of ferruginous material in some of the beds. From the conspicuous development of the same series on Shotover Hill near Oxford we have entitled these deposits, "the Shotover Sands."

These Ironsands form the tops of prominent hills, which rise boldly to a height of 100 to 150 feet above the surrounding plain of the Upper Jurassic clays, and are evidently the relics of an originally extensive deposit, of which the greater part has been removed by denudation. On Muswell Hill, the most northerly of the outliers, the Ironsands occupy an irregularly oval area having an extreme length of 1,400 yards and an average breadth of about 500 yards. On the south-east, this tract extends to within 500 yards of the north-western edge of the Brill outlier, being separated from it only by a shallow gap of erosion in which the Kimeridge Clay is exposed. The picturesque little town of Brill stands on the well-marked plateau formed by the Ironsands of the second outlier, which owes its level summit to the cementation of the sands into tabular concretions of ferruginous grit in the uppermost remaining beds of the group. This little plateau is deeply indented on all sides by short steep-sided combes or valleys, excavated by the springs which well out from the Ironsands or from the underlying pervious Portlandian strata resting upon the Kimeridge Clay.[1] The outlier is elongated in the same direction as that of Muswell Hill, from N.W. to S.E., and is close upon one mile in its greatest length. Although, owing to the prevalence of current-bedding and lenticular stratification, it is not possible to determine the dip from particular exposures, a gentle inclination of the Ironsands towards S.S.E. is brought out by the mapping, the base of the group falling from the 600-feet contour-line at the northern end of the Muswell Hill outlier, to the 500-feet line at the southern end of the Brill outlier. The underlying Portlandian Beds show a corresponding inclination, so that the unconformity between the two series, deducible from wider evidence, is not apparent in this district.

The Ironsands appear also to lie in a very slight trough, of which the axis runs centrally to the major direction of the outliers; but owing to the downwash of the sands on the steep rising ground this structure cannot be demonstrated with certainty. If present, it may be due either to a gentle synclinal flexure of the strata, or to a slight hollow of erosion formed previously to their deposition.

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[1] [Including here the Hartwell Clay.—H.B.W.]

In composition, the Ironsands show much local variation, while maintaining their general characters with a fair degree of constancy. This is very well seen in the numerous excavations on Brill Common which occupies the steep northerly slope of the Brill outlier, where the sands have been dug for building and other purposes, and the clays and silts for making bricks and tiles. Only a small portion of the group is seen in any particular section; but as the excavations range from top to bottom of the hill, almost the whole sequence is exposed here, though the lowermost portion is confused by slipping. By combining this evidence, the following generalized section of the Brill Ironsands in downward succession has been obtained:—

GENERAL SECTION OF THE IRONSANDS ON BRILL COMMON.

Description.	Where best seen.	Average thickness.
Top soil, brown sandy loam full of of fragments of ironstone	...	1 to 3 ft.
1. Loamy ferruginous sand and sand-rock, with tabular concretions of ironstone, and much streaked with smooth whitish clay	Sand-pit in field at crest of hill 200 yds. N.W. of Brill Police Station	5 ft.
2. Fine buff or white sand, with ferruginous bands and incipient ironstone concretions, and a few clayey streaks, passing down into—	Same locality; and lower part in sand-pit 25 yds. S. of Mill Cottage, Brill Common	10 ft.
3. Ashy grey and brown fine loamy sand, silt and grey silty clay, with traces of plants		5 ft.
4. Very fine sharp white sand with filmy streaks of clay	Ditto	4 ft.
5. Shaly brown and lavender clay and loam, with traces of plants	Clay-pit east of Mill Cottage	4 ft.
6. Fine white or ashy-grey sand and sand-rock, with thin laminæ of clay and some hollow ironstone concretions	Sand-pit at the northern Windmill, and another pit 20 yds. S. of the southern Windmill	10 ft.
7. Ochreous clay, with concretionary ironstone showing obscure traces of fossil shells and plants	Ditto	4 in. to 6 in.
8. Ashy grey, lavender and brownish loam with layers of sand, showing traces of plants	Ditto	5 ft.+

Base not well seen, resting on Purbeck Beds (see p. 62) in the stone-pit adjoining high road, at east side of Common, 300 yds. N. of Temple Farm; and in old clay (?) pit on west side of Common (see pp 62-3.) Total thickness, about 45 ft.

With the exception of indeterminable fragments of plants, fossils are very rare in these deposits, but there is clear evidence that the beds have been laid down in fresh water. From an ironstone band at Brill, the Rev. P. B. Brodie obtained "a small *Paludina*, coarsely but strongly ribbed, and apparently distinct from any figured and described by Professor Phillips" [from Shotover].[1] The only shells found at Brill during our survey were the obscure indeterminable casts in ironstone mentioned in the above section; but blocks of similar ironstone, found rather abundantly at about the same horizon in the banks of the road and the adjacent ploughed fields on the south-eastern slope of Muswell Hill, within half a mile of Brill Common, were frequently crowded with recognisable casts of *Cyrena media*, J. de C. Sow., and in one instance with *Unio porrectus*, J. de C. Sow.[2] Fitton,[3] in his account of the Brill sections, describes the occurrence, in a clayey bed (probably No. 5 of the above section), of an entire tree, converted into pyritous lignite, full 40 feet long, the trunk about a foot in diameter, with branches that extended to about 10 feet beyond it on both sides. The position of the clay-pit from which this tree was obtained is given as "about 20 feet below the road on the south-west [?] of Brill."

Besides the direct evidence afforded by these fossils, there is the further fact that the more fossiliferous Ironsands of Shotover, which clearly belong to the same series, as will presently be shown, contain only fresh-water fossils. The occurrence of the thin band of Purbeck Beds at the base of the Ironsands of Brill, as already described, has an important bearing upon the question of the age of the latter series. These Purbeck Beds plainly indicate the change from the purely marine conditions of the underlying Portlandian deposits to the brackish water and variable conditions following upon a recession of the sea; and in the Ironsands we have indications of the succeeding stage, when the district rose entirely above sea-level and the only deposits were those of fresh-water origin. This stage presumably followed directly upon the estuarine episode; and the deposits are therefore only slightly newer than the Purbeck, *i.e.*, they represent the lowermost part of the Wealden series of Kent and Sussex, and may be roughly correlated with the Hastings Beds, but are probably older than the Weald Clay. The fresh-water fossils are, unfortunately, so few in species, and these so little known, that the evidence for this correlation must rest mainly upon the stratigraphical relations of the Ironsands.

The belt of silty clay which occurs in the section on Brill Common gives rise to small springs in this locality; but the main outflow of water, both from the Brill and from the Muswell Hill outlier, comes from the Portland Beds, showing that neither the clays associated with the Ironsands, nor those of the underlying Purbeck, are sufficiently persistent to arrest the percolation of water downward into the Portlandian strata. At the same time it is noteworthy that the Ironsands of Shotover also include a clayey zone which occurs in approximately the same position as at Brill (see p. 69). Like most river-deposits, the varied sediments tend to arrange themselves in elongated lenticles, and not in regular layers like the sediments of deeper and quieter waters.

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[1] *Quart. Journ. Geol. Soc.*, vol. xxiii. (1867), p. 198.

[2] An example of *Unio* was also obtained in 1893 during an excursion of the Geologists' Association. *Proc. Geol. Assoc.*, xiii., p. 73.

[3] *Trans. Geol. Soc.*, ser. 2, vol. iv. (1836). p. 280.

On Muswell Hill the Ironsands are scantily exposed, the only sections being the much overgrown road-cuttings at the eastern and western ends of the hill, and the small sand-pits at the two farmsteads on its south-western flank. Streaks of damp clayey soil occur in relatively the same position as at Brill, and the generalized Brill section given above is probably representative for the Muswell Hill outlier also. No indication of the presence of Purbeck Beds between the Ironsands and the Portlandian strata was, however, observed in this outlier.

Shotover Hill.

Shotover Hill, 2½ miles east of Oxford, owes its prominence to a thick capping of more or less ferruginous sand, with some interbedded clay-beds, and much concretionary ironstone, the latter being especially abundant in the upper part of the series. These beds form the flat crest of the long narrow ridge which extends E.S.E. for over 1½ miles nearly to Wheatley. South of Littleworth the Ironsands are cut out for 300 yards or so by a depression in the ridge, but they reappear in the rise of the ground beyond this space, and are then prolonged in another ridge which sweeps round southward from Wheatley for about two miles, nearly to Garsington. These ridges form two separate outliers of the Ironsands, surrounded by the Portlandian Beds which occupy their slopes, while a third outlier is formed by a small patch of the ironstones and sands which occupy the summit of Red Hill, one mile north of Wheatley.

The springs which burst out around the margin of the two larger outliers, where the pervious Ironsands and Portland Sands rest upon the Kimeridge Clay, have deeply indented the ridges, thereby giving an irregularly lobate outline to their borders.

The ferruginous sands of Shotover, along with those of the similar outliers at Brill, lying six miles to north-eastward, were originally considered as forming part of the marine Lower Greensand Series. The discovery by the Rev. H. Jelly, of Bath, that fresh-water shells belonging to the genus *Paludina* [at present known as *Viviparus*] occurred in the Shotover Beds, first made known by H. E. Strickland in the year 1834,[1] showed that these deposits could not have been accumulated under marine conditions, and in 1836 Strickland[1] classified them as doubtfully Wealden.

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[1] *Proc. Geol. Soc.*, ii., p. 6.

Phillips, at a later date, added considerably to our knowledge of the Shotover Sands,[2] and described and figured the fossils, which he found to be all fresh-water forms; he concluded that the deposits "may at present, with much probability, be referred to the Hastings Sands; it is, however, possible that they may be an estuarine deposit of the Lower Greensand age." The occurrence of several species of fossil Ostracoda in the Shotover Ironstone was afterwards recorded by Prof. T. Rupert Jones.[3] Prestwich, also, at a later period, accepted the view that the Shotover Sands were of the Wealden age.

Up to about 1875 it was recognised that the fauna of the Shotover Sands was wholly fresh-water;[4] but a few marine fossils that were found subsequently, in a matrix of sandy ironstone, seemed to imply the association of a marine bed with the sequence. One of these fossils, mentioned by Dr. J. J. H. Teall (see p. 51), was a cast of *Trigonia gibbosa*, var. *damoniana*, and it was suggested that this might indicate a gradual passage from Portland to Ironsand conditions. Others, including *Perna* and *Modiola?* are preserved among the Ironsand fossils in the Oxford Museum. It was found, however, during the recent survey, that there has been an alteration in places of the uppermost part of the Portland Beds into ironstone and into a peculiar cherty rock, probably through the percolation of mineral waters from the overlying Ironsands; and the presence of marine fossils in an ironstone matrix on Shotover Hill may, we think, be thus explained. The interesting petrological characters presented by this altered rock have been described by Mr. H. H. Thomas (p. 52).

In fact, like the Brill outliers, the Ironsands of Shotover and Wheatley appear to be entirely of fresh-water origin; and the preservation of small patches of estuarine Purbeck Beds at their base in the sections at Combe Wood and Garsington, described by Fitton (see p. 61), adds further to the similarity. The reasons for correlating the Brill deposits with the lower portion of the Wealden Series have already been stated, and the same correlation will apply in the present case, a result which agrees with the earlier opinions regarding the age of these beds.[5] On these grounds the fresh-water

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[1] In a note contributed to Fitton's celebrated memoir, "On the Strata between the Chalk and the Oxford Oolite," &c. *Trans. Geol. Soc.*, ser. 2, iv., p. 527.

[2] "On the Estuary sands in the upper part of Shotover Hill." *Quart. Journ. Geol. Soc.*, xiv. (1858), pp. 236–241; also Geology of Oxford, &c., 8vo. Oxon. (1871).

[3] *Geol. Mag.*, 1878, pp. 103–110 and p. 277; see also *Quart. Journ. Geol. Soc.*, xli. p. 320.

[4] Prof. J. F. Blake rather unfortunately applied the term "Shotover Sands" to the Portland Sands of Shotover. *Quart. Journ. Geol. Soc.*, xxxvi., Plate VIII. See also Morris, *Proc. Geol. Assoc.* ii., p. 36.

[5] This opinion is also endorsed by Mr. A. M. Davies in his excellent paper entitled, "Contributions to the Geology of the Thame Valley." *Proc. Geol. Assoc.*, xvi. (1900), p. 53.

Ironsands have been separated on the new map from the sands of Lower Cretaceous age that are considered to be of marine origin, and the two groups are distinguished by different colours.

Description of Sections.—The ironsands on Shotover Hill were formerly dug on an extensive scale for ochre, but this industry has long since died out, and the old pits are now either obliterated or greatly obscured. The largest workings seem to have been on the site of the present "allotment gardens," ½ mile north of Horsepath, and in the park-land N.W. of these gardens 100 yards N. of the old coach-road. In the latter locality there is still a partly exposed section showing several feet of yellow sand with intercalated ironstone and traces of clayey beds below; some further account of these sections, compiled from early descriptions, will be given (see p. 132). The best exposures at present available occur in small pits at the western end of the hill, of which some details will be found in the context, and there are also small pits at the eastern edge of Horsepath Common and on the hill south of Wheatley, besides some, more or less obscure, road-cuttings. By combining all the available data, the following generalized section of the series on Shotover Hill in downward succession has been deduced. The prevalent similarity of this section to that of the corresponding series at Brill (p. 65) has already been remarked upon:—

GENERAL SECTION OF THE IRONSANDS ON SHOTOVER HILL.

Description.	Where best seen.	Average thickness.
Top soil, brown sandy loam full of fragments of ironstone	...	1 to 3 ft.
1. Rusty sand with much tabular concretionary ironstone, forming the top of the plateau, mixed with and passing down into yellow and orange sand, no fossils seen	Old ochre pits north of Horsepath Common	15 ft. seen, but may be thicker.
2. Grey or white clay, like fuller's earth, probably impersistent: causes slipping on the hill-sides	Pit on western crest of Shotover Hill, 80 yds. N. of road	3 to 5 ft.
3. Very fine white or greyish sand and silt, sometimes stained buff, yellow or orange, occasionally streaked with clay: though variable, is fairly persistent as a whole	Ditto	12-15 ft.
4. Coarser sand, white, yellow or brown, with hard purple ironstone concretions, sometimes containing casts of fresh-water shells and bits of plants: with occasional streaks or bands of grey or ochreous clay up to 1 ft. in thickness, including unfossiliferous claystone nodules	Sand-pit at E. side of Horsepath Common, 200 yds. south of "Rough Barn"; also poorly exposed in old pits at west end of Shotover Hill, and at slipped section mentioned below	8-10 ft. seen, but may be thicker.
5. Coarse speckly sand, with crumbs of white earth (? decomposed clay-pellets) and decayed ironstone concretions: resting on stained Portland Beds (see p. 51.)	Small sand-pit east of reservoir on western spur of Shotover Hill (perhaps slipped)	1-2 ft.

Total thickness, about 50 ft.

The pit on the western crest of Shotover Hill, mentioned above, deserves particular mention, because of the somewhat exceptional character of the beds and the presence of fossils. The following was the section exposed in it at the time of the survey. in Aug., 1904:—

Section in small pit at western crest of Shotover Hill, 80 *yds. N. of the old coach-road.*

1. Ferruginous soil, with many fragments of ironstone; shattered flaggy ironstone at base in places	2 to 3 ft.
2. Ochreous yellow sand, streaked with very fine pale yellow silt with dark lamina, indurated to sand-rock in places	about 3 ft.
3. Smooth pale grey or whitish clay, with ochreous streak at base; thickness variable	1 to 3 ft.
4. Very fine greyish-white silt, almost like clay, passing imperceptibly into loam; with large fossiliferous concretions of purple ironstone at base	seen to 5 ft.

The fossils in No. 4 occur in the form of sharp empty casts in the hard ironstone, chiefly of the so-called *Paludinæ* (*Viviparus ornatus* (Phill.) and *Viviparus* sp. indet.) with an occasional *Unio* and some obscure plant-remains. It is noteworthy that this assemblage is different from that of the fossiliferous ironstone of the same series near Wheatley, where *Cyrena* is the most abundant shell. But as the character of the series seems to imply its comparatively rapid accumulation, it is probable that this difference represents the segregation of species to such portions of the fluviatile area as were most suitable to them, and that it does not denote a true faunal succession.

The fine white silt (No. 4) of the above section is carefully dug and sent out of the district for use in some manufacturing process. (See page 131.)

Conybeare[1] gives the following section of the "Ochre pits, Shotover Hill," probably those north of Horsepath, to which reference has been already made (see also page 69):—

	Ft.	in.
Beds of highly ferruginous grit, forming the summit of the hill	6	0
Grey sand	3	0
Ferruginous concretions	1	0
Yellow sand	6	0
Cream-coloured loam	4	0
Ochre	0	6

"Beneath this is a second bed of ochre separated by a thin bed of clay; then succeeds an interval of nearly 40 feet occupied by various alternations of ferruginous and sometimes cherty and argillaceous loams of a deep cream colour." This section is reprinted by Phillips,[2] who estimates the total thickness of the series at 80 feet, but it is more probable that the maximum does not exceed 60 feet, the apparently greater thickness being due to slipping and downwash on the slopes. Phillips mentions that the fossil-casts are not confined to one horizon but occur throughout the series except possibly in the uppermost 20 feet.

The Ostracoda recorded by Prof. T. Rupert Jones occurred in some pieces of ironstone picked up by Mr. H. Caudell in the vicinity of old stone pits at the western end of Shotover "Common" [Plain], which also contained casts of *Unio*, *Cyrena*, *Paludina* and bones of fish.[3] During the recent survey, ironstone with casts of shells (*Cyrena media*, J. de C. Sow.; *Unio* cf. *cordiformis*, J. de C. Sow., and *Viviparus*) was also collected from the débris of the old pits in the Allotment Gardens north of Horsepath and on the spur of the hill east of Horsepath Common, 300 yards N. of Westhill Farm.

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[1] "Outlines of the Geology of England and Wales," by Conybeare and Phillips; Lond. 1822, p. 139.

[2] *Quart. Journ. Geol. Soc.*, vol. xiv. (1858), p. 238; and Geology of Oxford, p. 413. See also footnote p 57, of this Memoir.

[3] *Geol. Mag.*, 1878, p. 103

The exposures of the Ironsands at present available in the outlier south of Wheatley, are confined to a few small pits and road-cuttings, none showing more than a few feet of sand with ironstone. An old wall on the western side of the high road at the margin of Combe Wood, ½ mile S. of Wheatley Station, is built of flaggy ironstone, probably obtained from an old pit in the Wood, now sloped. This ironstone is crowded with the casts of fresh-water shells,[1] chiefly *Unio* (an elongate form), and *Cyrena media* J. de C. Sow., with occasional *Viviparus*. The fossils of the Ironsand series may be obtained more readily from this place than from any other locality at present available either in these outliers or in those around Brill.

Similar material seems at one time to have been exposed in an old pit 200 yds. E.S.E. of the Windmill at Wheatley, where ochre and iron-ore were dug. Prestwich[2] describes this pit as being about 12 feet in depth, consisting of beds of rubbly iron-sandstone, impure limonite, and yellow ochre, and "at the depth of about seven or eight feet a thin seam of iron sandstone, at the base of the main bed, six or eight inches thick, was literally full of casts and impressions of these shells—chiefly *Cyrena* and *Paludina*; while another thin band was covered with ripple-markings and matted with indeterminable plant impressions." Casts of *Cyrena media* were also noticed during the recent survey in ironstone fragments on the surface of a field 600 yds. west of Slay Barn and on the slopes south-east of Hill Farm. The section in Combe Wood, described by Fitton, in which Purbeck Beds were seen below the Ironsands, has been previously referred to (p. 61).

Toward the southern end of the Wheatley outlier the beds appear to become more clayey, but the boundaries are difficult to trace, and may have been extended a little too far on the map. In the previous memoir ("Parts of Oxfordshire and Berkshire," p. 11, Fig. 2), a section exposed in a road-cutting one mile north of Garsington is figured and described, in which beds of variegated sands and clays with bands of ironstone were seen to overlie an eroded surface of Portland limestone. Fitton (*op. cit.*, p. 277) also describes a stone-pit at Garsington which showed 8 feet of ferruginous sand with bands of clay and ochre, resting on Purbeck Beds (see also p. 55).

The base of the series, as a whole, shows a very gradual and almost imperceptible dip toward south-east. In view of the similarity now known to exist between these beds and the stained top of the Portland Beds, there is no satisfactory evidence for the supposed overlap of the series northward on to the Kimeridge Clay which was represented on the previous geological map; on the new map, therefore, the Portlandian Beds are represented beneath the Ironsands in every part of the Shotover and Wheatley outliers. The revision near Wheatley was made in 1897 by J. H. Blake. (See p. 54)

Main Outcrop South of Waterstock.

With respect to the Lower Cretaceous shown on the map as extending in a narrow strip from Tiddington, past Chilworth Farm to Great Milton, we have, in the absence of clear sections, no definite information, excepting that supplied by the sandy character of the soil and the presence of brown sand in shallow ponds and ditches. In this tract the sands appear to rest directly upon Kimeridge Clay, but to the east of Great Milton there are indications that they pass unconformably over the Portland Beds. A little farther southward, where a sandy and clayey series is seen to rest directly upon the Portland Stone, these beds are almost certainly of fresh-water origin, as will presently be shown; but it is possible that the uppermost beds, just below the base of the Gault, may belong to the newer marine series, and may unconformably overlap upon the fresh-water series, as well as upon the Portlandian rocks. This is, however, a hypothetical suggestion for which no direct evidence is forthcoming.

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[1] G. W. Lamplugh, *Geol. Mag.*, 1902, p. 574 (*letter*)
[2] *Geol. Mag.*, 1879, p. 194.

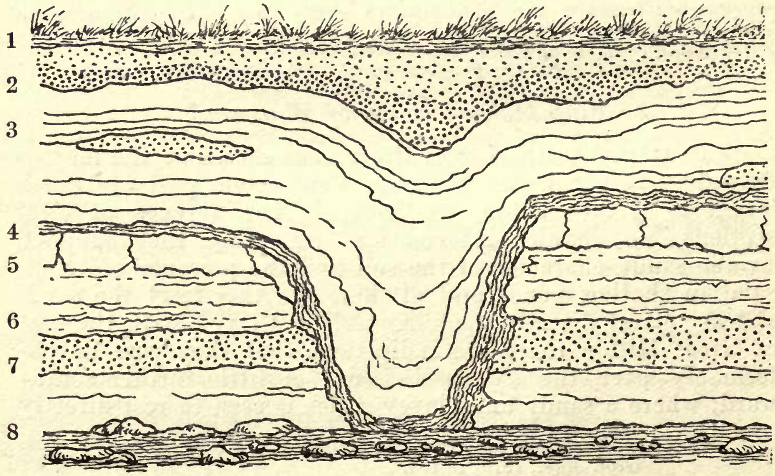
At present the best exposure of the sands and clays above referred to occurs at Great Milton, where the outcrop of the Lower Cretaceous beds expands considerably and is probably continuous to Great Haseley, and thence to the eastern margin of the map. The following section is exposed in the stone-pit at east side of the village, where the strata overlying the Portland Stone at the time of our visit in August, 1904, were :—

	Ft.	in.
Top soil, removed.		
Laminated grey and yellowish clay and loam with streaks of sand, and a lenticle of soft ferruginous stone, passing into—	4 to 6	0
Greyish white and yellow rather fine-grained sand and sand-rock, streaked with dirty-grey and brown loamy beds : with curiously broken bedding in one place at south side of pit ... ... about	6	0
Pebbly ferruginous sand, with smooth lydites up to ½ inch in diameter : greyer below, and with "box-stone" ferruginous concretions at base ...	1 to 2	0

resting on a rough hummocky surface of Portland Stone (p. 59).

The only traces of organic remains detected in these beds were some obscure fragments of vegetable matter in the soft ironstone-lenticle in the top clays, but in their general characters these clays closely resemble the clays interbedded with the fresh-water beds of Shotover Hill, though the coarse ferruginous sand at the base approximates more closely in character to the marine sands of Culham. In the south-eastward extension of these beds at Great Haseley, however, definite evidence for their fresh-water origin is forthcoming. The old stone-pits east of the Great Haseley Allotment Gardens, about a mile south-east of the above-described section, are now partly overgrown with vegetation and very obscure, though it can still be seen that, above the Portland Stone, a thick bed of grey clay with

FIG. 10.—*Stone-pit at Great Haseley (Fitton).*



ochreous ferruginous concretions has been passed through. This was visible to a depth of about 3 feet, while at the top there are in places deep "pockets" of ironstone-rubble mixed with sand, the remnants of beds that originally existed above the clays. (See pp. 59, 60.)

Fitton saw a clear section in "the principal quarry at this place" and illustrated it by the following description, and by the figure (Fig. 10) reproduced opposite [1]:—

	Ft.	in.
"1. Soil forming a level and uniform surface.		
"2. Loam, brown and red; containing fragments of ferruginous conglomerate (carstone) and of a brown substance, like umber; passing below into ferruginous sand	3 0 to 0	6
"3. Thinly stratified firm clay or marl, of a light grey colour, approaching to stone, not effervescent, containing between the folia impressions of plants, and including portions of reddish sand, in horizontal masses of very unequal thickness.	6	6
"4. Dark brown clay; . . . Some of the masses into which it is easily divided are polished by sliding on each other under pressure. At the bottom ferruginous sand alternates with the clay	1 0 to 1	6

["All the preceding beds are much disturbed, and bent irregularly, so as to accommodate themselves to a chasm in the strata below—here called a 'Gull' (gulley ?) . . .]"

5, 6, 7, 8, Calcareous stone-beds and sands (Portlandian) see p. 59.

Fitton does not mention the presence of any fossils, except vegetable remains in the beds above the Portlandian, but thirty years later Phillips[2] gave a more detailed account of these strata and recorded the discovery of fresh-water shells in the topmost bed.[3] The following is his description of the section:—

"Section at Great Haseley." (Phillips).

"12. Soil, uniformly spread, with drift on the surface of chalk flints, and red grit pebbles.

"11. Brown sand and laminated ferruginous sandstone or ironstone, with some argillaceous parts *In this bed* Paludina elongata *and others, lying in separate short tracts or nests, as at Shotover Hill*. Thickness 3 to 5 ft. seen.

"10. The lower surface is undulated in a surprising manner, and rests on a yellowish or white laminated clay, with thin brown irony bands. Thickness, 3 to 5 ft. The bottom rests level on the next bed.

"9. Brown ferruginous level sands, false-bedded, the lamina dipping N.W. . . . 1 ft. 6 in.

"8. Dark irony band . . . 3 in.

"7. White laminated clay . . . 1 ft. 6 in."

and 6, 5, 4, 3, 2, 1, a succession of white, blue and brown laminated clay-beds with ferruginous and sandy bands, having a total thickness of 7 ft. 3 in.

The general character of the strata above the Portland Stone in these descriptions agrees so closely with that of the beds exposed in the pit at Great Milton, that we must accept the presence of fresh-water shells at Great Haseley as proof of the fresh-water origin of the former also; though, as already noted, it is still possible that a thin representative of the marine sands may intervene between these beds and the base of the Gault north of Great Haseley, where there are unfortunately now no adequate exposures.

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[1] "Observations on some of the Strata between the Chalk and the Oxford Oolite. . . ." *Trans. Geol. Soc.*, ser. 2, iv. (1836), p. 276.

[2] Geology of Oxford, (1871), p. 417.

[3] The discovery of *Paludina* at Great Haseley appears to have been made by the Rev. P. B. Brodie. See Wright, "Mon. Brit. Foss. Echinodermata of Oolitic Formations," (1859), i., p. 354.

Outliers East of the River Thame.

Immediately to the south of Great Haseley there occurs an irregular strip of clayey ground, with sandy patches, that is separated from the main outcrop only by a narrow belt of the Portland Beds on which the village itself stands. This is in the line of the Wheatley disturbance (see p. 39), and probably represents a patch of the Shotover Sands brought in by the slight southward drop at the fault. Around the village of Little Haseley, whitish clay, overlying sand, was observed, as noted further on. The composition of these two outliers, as well as their relation to the main outcrop, links them with the fresh-water series. A third outlier occurs on the low ridge overlooking the Thame, half a mile S.W. of Great Milton, which is capped with sandy ferruginous soil containing many fragments of ironstone; from its position and lithological characters this outlier also probably belongs to the Shotover Sands.

To the east of Great Milton, and south of Silver Cottage, Mr. J. H. Blake noted 3 feet of fuller's earth of whitish colour. White clays of this character occur beneath the ironstone, and were seen by Mr. Blake east of the Mill House.

The following notes are by Mr. Woodward:—

Similar clays occur also in the old stone-pit north of the School at Great Haseley. To the south of the village there is a belt of clayey ground, part of a tract marked on the original Geological Survey map as Gault. There was no good section observable anywhere in this tract; the soil was slightly sandy and loamy, but in the main it was clayey.

Difficulty arose also in deciding the nature of the ground between Haseley Wood and Little Haseley, until, fortunately, a well dug at the western end of Little Haseley Village, proved 8 feet of whitish clay over sand. The clay was like that south of Silver Cottage, Great Milton, and in the old stone-pit of Great Haseley. (See p. 72.)

The same clay is seen in the pond at Little Haseley, and west of the "Sportsman's Retreat." A little further west stone was formerly dug. H. B. W.

Combining the evidence regarding these scattered patches of Wealden fresh-water deposits that lie to the east of Oxford (excluding the independent masses of Brill and Muswell Hill), we find that all the outliers fall within a comparatively narrow belt that runs south-eastward from Shotover to Great Haseley. The beds in this belt are always underlain by Portland rocks, except in their doubtful extension north of Great Milton, and in a few places where lenticles of Purbeck Beds intervene between the two formations.

The base of the series also declines very gradually toward the south-east, probably under the influence of the structural dip of the country generally, and descends from the 500-feet contour at the west end of Shotover to about the 300-feet line where the beds disappear beneath the Gault near Great Haseley.

CHAPTER VIII.

LOWER CRETACEOUS—(*continued*).

BY G. W. LAMPLUGH.

LOWER GREENSAND.

Besides the Ironsands of Shotover and Brill, there are, within the area of the map, several other outlying patches of sand of the same general character, with interstratified beds of clay, that occupy a similar stratigraphical position, between the base of the Gault and the top of the Jurassic strata; and a narrow strip of these deposits may also crop out beneath the Gault in the south-eastern part of the map. Unfortunately these beds are in most places devoid of fossils, so that it is very difficult in many instances to decide whether they belong to the fresh-water series of Shotover and Brill, or whether they represent the salt-water sediments laid down during the marine transgression that is known to have ensued during the later stages of the Lower Cretaceous period.

At this period the earlier formations that rose above sea-level were planed off by the encroaching sea, so that the deposits of this age are markedly unconformable to the strata on which they rest. Owing to the low dips which prevail throughout the district, it is rarely, however, that this unconformity can be detected in any particular section, but it is brought out clearly by the mapping of wide areas. As this marine transgression took place after the deposition of the Ironsands, it is highly probable that the original limits of these sands were very considerably reduced by erosion during this stage, and therefore that the newer marine deposits of the Lower Cretaceous system are unconformable to the older fresh-water beds.[1] This relationship, however, can only be inferred, as there is no section in which the contact of the marine with the fresh-water beds has been recognised.

With the doubt that must exist in many places whether the beds belong to the fresh-water or to the marine group, it will be advisable to deal separately with the different areas in which the deposits in question occur, so that the evidence in regard to them may be independently considered. The present writer is at a disadvantage in this matter, through not having himself surveyed these tracts, his knowledge of them being confined to some scattered personal observations made during a traverse of parts of the ground, and to the notes recorded by his colleagues on the six-inch maps, &c., during the survey.

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[1] This view of the relationship of the marine Lower Cretaceous beds to the underlying strata is very clearly brought forward by Mr. A. M. Davies in his paper on the "Geology of the Thame Valley," already referred to (p. 68).

HURST HILL AND BOAR'S HILL OUTLIERS.

The long irregular ridge of Boar's Hill, three miles S.W. of Oxford, rapidly becoming the site of a residential suburb of the city, is capped with a thick mass of coarse ferruginous sand containing much concretionary ironstone. Similar material also occupies the crest of Hurst Hill, which lies along the same axis, but is separated from the main ridge by a deep hollow and thus forms a small outlier 600 yards north of the main mass. Other still smaller isolated patches of red sand, much obscured by gravelly drift, lie on the north-eastern side of the main ridge.

At Hurst Hill the strata are well exposed in the Chawley Brickyard, where the Kimeridge Clay is dug beneath the sands (see p. 46). The upper part of this section is much disturbed, either by glacial action or by ancient landslips, or both, so that patches of drift gravel and strips of blue clay, proved by fossil-evidence to belong to the Gault (see p. 80) as well as portions of Kimeridge Clay, are curiously entangled among the Lower Cretaceous Sands. Where the latter are comparatively undisturbed they consist of very ferruginous coarse sand showing well-worn quartz grains and small pebbles (especially toward the base), up to three-quarters of an inch in diameter. In places they are indurated into lenticular masses of sand-rock, and also contain ironstone concretions of the "box-stone" type, *i.e.*, with a hard crust surrounding and enclosing patches of incoherent sand. These beds are exposed to a maximum depth of 16 feet in the pit. They have as yet yielded no trace of fossils; but in the coarse grain of the sands, their well-worn aspect, and the presence of small pebbles, they bear a closer resemblance to the beds that are known to be marine[1] than to the fresh-water Shotover Sands, in spite of their relative proximity to the latter. The fact that they rest directly upon the Kimeridge Clay, which implies the previous removal of the Portlandian Beds, lends further support to the view that they were accumulated during the later Lower Cretaceous stage of marine transgression and not during the early stage of fresh-water conditions. On these grounds they are represented as part of the marine "Lower Greensand" on the map.

On Boar's Hill the sands are of the same character as in the Chawley section. They have been penetrated in numerous wells sunk for the water-supply of the new houses; thus, opposite the house named "Hillcrest," a well, reported to be 50 feet deep, was entirely in ferruginous sand with concretionary ironstone; and at another, about half a mile farther south, adjoining "Foxcombe," 35 feet of the same sand was passed through, and it was stated that the "blue clay" (Kimeridge) would be reached at a further 5 feet below.

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[1] This resemblance was commented on in the previous memoir : on the Geology of parts of Oxfordshire and Berkshire, (Sh. 13), p. 15.

NUNEHAM COURTENAY.

A broad tract of Lower Greensand was shown in the original Geological Survey map as covering Nuneham Park, and extending northward to Toot Baldon. In the new series map Sheet 254, which was colour-printed in 1905, Lower Greensand was represented over the area of March Baldon, to the northern margin of the map at Baldon Row, as surveyed by J. H. Blake.

The mapping of this tract has been admitted by all who have examined the ground, to present many difficulties, but as elsewhere noted (see p. 56), evidence has now been obtained to show that Portlandian beds occur over parts of the area, probably from the northern confines of Nuneham Park across the uplands of March Baldon and Toot Baldon, and eastwards towards Chislehampton.

The evidence of fossils indicates conclusively that Lower Greensand occurs at Culham and Clifton Hampden to the south of Nuneham Park, just beyond the limits of our present area, and that Portlandian occurs at March Baldon and Toot Baldon on the north. The lithological evidence, as already pointed out, shows that the Lower Greensand locally consists of coarse and ferruginous pebbly and quartzose sand; the Portlandian of fine-grained sands and sandstone.

That the Lower Greensand is subject to rapid changes in thickness is shown in the brickyard section at Culham, where it is diminished to a few inches, though seen to a depth of 10 feet in a sand-pit only 150 yards farther west. In this sand-pit the strata consist of coarsely gritty ferruginous sand with small pebbles, shown to a depth of 12 feet; and similar material, still more pebbly, is exposed in a low cliff on the Thames bank at Clifton Hampden. The beds in this region are locally indurated into rocky layers.

In a MS. description of the neighbourhood, written by Daniel Sharpe,[1] there is a statement that organic remains had been obtained from the sand

> "in a low bank by the side of the road which slopes from a turnpike in the Abingdon road down towards the ferry at Clifton: they are the following species in the state of ferruginous casts occasionally preserving the outer surface:—*Exogyra conica*, *Terebratula ovata*, *Rhynchonella octoplicata*, and *Rhyn. Hampdeni*, a new species found also in the Upper Greensand of Warminster."

That these are marine deposits, is further indicated by the presence of marine fossils in the pebbly layer between the Gault and the Kimeridge Clay in the Culham brickyard section. Phillips[2] recorded a *Pecten* and an *Exogyra* from this bed; and the present writer, in a brief examination of the pit, in the summer of 1902, found the casts of several shells, including a small oyster and a *Trochus*-like univalve.

By Mr. Jukes-Browne the pebbly sand in the brick-pit has been regarded as the basement-bed of the Gault, which is considered to cut out the Lower Greensand at this point;[1] but the indurated portion of the sands in the adjacent sand-pit also contain markings that appear to be the casts of fossils, and recently a large specimen of *Exogyra sinuata* has been found in a bed of coarse laminated sandstone at Culham.[2] Some fossils have lately been collected for the Geological Survey, by Mr. J. Pringle, in the sand-pit west of Culham Brickyard; they include the following:—

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[1] Preserved in the Library of the Geological Survey and Museum.

[2] *Quart. Journ. Geol. Soc.*, xvi. (1860), p. 309; and Geology of Oxford, p. 428.

Radiopora, sp.
Exogyra sinuata, *J. Sow.*
cf. Venus orbigniana, *Forbes.*

Mr. J. H. Blake had noted exposures of Lower Greensand north of Hill Farm and by Warren Farm, north of Culham; also eastwards to the railway. These comprise pebbly sands of like character to the Lower Greensand before mentioned.

By Rough Lodge, south-east of Nuneham Park, Mr. Blake, in 1896, recorded that a brickyard had been opened in 1852, and had since been abandoned. He noted 4 feet of coarse quartzose sand resting on 4 feet of thinly-bedded, coarse, ferruginous sandy rock, locally known as "Roach." Dark blue clay was said to have been dug, and clay also was said to have been obtained from Clifton Heath, where an outlier of Gault has been mapped.

Coarse, pebbly and quartzose sand was noted by Mr. Blake, in Lock Wood, on the western side of Nuneham Park. There the material, known as "Roach," has been used for making paths. Similar sand was observed by Mr. Blake to the east and north-east of the Mansion in Nuneham Park. Here the difficulties of distinguishing Lower Greensand from Portlandian are complicated by the presence of patches of Drift sand and gravel, and the absence of good sections. (See p. 58.)

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[1] "The Cretaceous Rocks of Britain," *Mem. Geol. Survey*, i., 1900, p. 268. See also H. J. O. White, Excursion to Culham and Wallingford, *Proc. Geol. Assoc.*, xviii., 1903, p. 300.

[2] "Discovery of *Exogyra sinuata* in the Lower Greensand of Culham, near Oxford," by C. G. E. Dawkins, *Geol. Mag.*, 1906, p. 94.

CHAPTER IX.

UPPER CRETACEOUS.

BY H. B. WOODWARD.

This group is represented in the area by Gault and Upper Greensand, which are united by Mr. Jukes-Browne under the general name Selbornian.

GAULT.

Of the small areas of Gault that occur in the district we have little precise information.

The Lower Gault, as observed by Mr. Jukes-Browne at Culham, to the south of Nuneham Courtenay, consists of a basement-bed of hard sandy clay full of small quartz pebbles, with a few phosphatic nodules, overlain by grey-laminated and micaceous clays.[1] It has yielded *Hoplites interruptus* (Brongn.), *Hoplites lautus* (J. Sow.), *Belemnites minimus*, Lister, *Dentalium decussatum*, J. Sow., *Inoceramus concentricus*, Park., *Nucula pectinata*, J. Sow., &c.

At a higher level the Lower Gault consists of stiff grey marly clay with glauconite grains and small phosphatic nodules.

The Upper Gault comprises a series of grey silty marls, belonging to the lower part of the zone of *Schlœnbachia rostrata* (J. Sow.). This species was obtained by J. H. Blake in Clare Brickyard, east of Warpsgrove. The full thickness of the Gault is probably about 200 feet.

Gault extends to the borders of the Alluvium, west of Latchford, and thence beyond Latchford Copse. Wells at Latchford are, at the more westerly farm, 40 feet deep, and at the cottage to the south-east about 50 feet deep.

Mr. J. H. Blake noted in 1900 that "The hill to the north-west of Chislehampton has been proved by a boring 60 feet in depth, made this year near the top of the sloping ground opposite Church Farm, to consist of bluish-grey clay, blackish in places It is apparently Gault overlying Kimeridge Clay."[2]

A small area of Gault was mapped by J. H. Blake on Pebble Hill, Toot Baldon—a hill named from a house called "The Pebbles" (now the Roebuck Inn), in the wall of which nine pebbles are inserted in the form of a diamond.

There are tracts of clayey ground on March Baldon Green, and around Windmill Hill in Nuneham Park. These may be Gault.

During the last few years the extensive excavation of Kimeridge Clay, at Chawley Brickyard, near Cumnor, has brought to light the existence of a bed of Gault clay above the Ironsand, but in a remarkably disturbed condition.[1] From this clay Prof. W. J. Sollas and Miss Healey obtained specimens of the Ammonite *Hoplites interruptus*,[2] while fragments of the same species were afterwards found *in situ* by Mr. Pocock.[3] (See p. 46.)

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[1] "Cretaceous Rocks of Britain," i., pp. 268, 275.

[2] Summary of Progress, *Mem. Geol. Surv.* for 1900, p. 120.

Dark blue clay has also been found in a well at the north end of Boar's Hill, overlying the ferruginous sand; and it was exposed in a field-drain close by. Judging by the evidence of the Chawley Brickyard, Mr. Pocock has little doubt that this clay is Gault.

UPPER GREENSAND.

A small tract of Upper Greensand comes within the area at Easington, east of Chalgrove.

The lower part of this group consists of calcareo-siliceous malmstone and layers of sandy and glauconitic marl, about 90 feet thick, beneath which springs are thrown out by the stiff clays of the Gault. The upper part consists of green glauconitic sand 10 or 12 feet thick. *Avicula gryphæoides,* J. de C. Sow., and *Pecten orbicularis,* J. Sow., were obtained from the malmstone of Clare Hill, north-east of Easington, where a good section was to be seen in the road-cutting.[4]

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[1] Attention was first called to these features in 1887, by Dr. F. A. Bather, *Journ. Oxford Univ. Junior Scient. Club,* 1888, p. 32.

[2] *Proc. Geol. Assoc.*, xix., 1905, p. 57.

[3] Summary of Progress, *Mem. Geol. Surv.* for 1904, p. 20.

[4] Jukes-Browne, "Cretaceous Rocks of Britain," i., p. 280

CHAPTER X.

SUPERFICIAL DEPOSITS—PLEISTOCENE AND RECENT.

BY T. I. POCOCK.

INTRODUCTION.

In the preceding chapters an account has been given of the different formations which constitute the so-called "solid geology" of the country. The youngest of them now remaining in the region is the Upper Greensand. But beyond these limits, eastward and southward, the Upper Greensand is overlain conformably in the Chiltern Hills and the Berkshire Downs by the Chalk which must once have spread far over the highest summits of the Oxford district.

Again, in the Lower Thames Valley, sands and clays of Eocene age are found extending up the dip-slopes of the chalk ranges, and in a few outliers, as at Nettlebed, attaining almost to the edge of the escarpments. It is clear that at one time they must have reached further to the north-west, but whether the estuary in which they were deposited extended over the site of Oxford, or was bounded by a coast-line of Chalk somewhere to the south-east, we do not know. In either case, any ground now existing in the Oxford region must have been deeply buried beneath the surface in Eocene times, for the highest hill is considerably lower than some of the Eocene outliers on the Chalk Downs. It is also uncertain whether the Pliocene submergence extended to the Oxford region. It seems probable that it did not, and that the country has been subjected to subaerial denudation ever since the Eocene period. Nevertheless, the great height which the Pliocene Beds attain at Lenham, on the Kentish plateau, and the depth to which the Lower Thames Valley has been eroded since that time, make it improbable that any part of the land-surface near Oxford can date back to the early Pliocene or Diestian age. There is, indeed, no proof that the Upper Thames Valley is older than the Pleistocene period.

The deposits of this period consist of alluvia formed by the rivers at various stages in the erosion of their valleys, and of hill gravels, probably of Glacial origin. Since the older deposits occur only as a few small outliers, whose age must be determined by reference to the wider-spread later alluvia, the most recent will be described first, and the others in the order of their antiquity.

ALLUVIUM.

Along the course of the Thames and its tributaries, slightly raised above the ordinary water-level, is a strip of flat meadow land for the most part uninhabited. After severe rains the whole of this tract is occasionally covered by water, but the floods must have been more frequent and protracted before the river-banks were built and the low grounds drained.

For unknown ages at every inundation the fine sediments brought down from higher lands have been spread out upon the flats, gradually raising their levels and filling the hollows worn in the older deposits. For the most part these sediments consist of fine silt, forming a lighter soil than the tough Oxford Clay. There were no good sections open at the time of the survey, but the alluvium was observed to be six or eight feet thick in the more central parts near the present water-courses. Sometimes it extends to the foot of a bank of Oxford Clay; but elsewhere, as in Ot Moor, it thins out so gradually that no definite boundary-line can be drawn. Fresh-water and land shells occur abundantly in places, as at Water Eaton, on the bank of the Cherwell. Those hitherto recorded are all species still living in the district.

Mr. E. S. Cobbold mentioned that in the vicinity of the Sewage Farm east of Sandford, "the bottoms of the small valleys which intersect the farm are filled with peat from four to six feet deep, in which have been found Roman pottery (at three feet), fresh-water shells, bones of deer, domesticated pig, cow, horse and dog. Under the peat, patches of gravel of very local character are found, quite unlike that in the Thames Valley."[1]

The alluvium does not rise with a perfectly uniform gradient up-stream, but tends to form lake-like expansions at slightly different levels above the narrower parts of the valleys. Thus, near the confluence of the Thames and Evenlode, under Wytham Hill, the passage is too narrow for the combined waters to escape, and in consequence floods spread over two and a half square miles of country near Stanton Harcourt. Other alluvial expanses occur at Cassington, Port Meadow, between Oxford and Iffley, and on the Cherwell between Kidlington, Islip, and Water Eaton. But by far the most important in the district is Ot Moor, a flat tract 193 to 205 feet above O.D. and upwards of six square miles in extent, overflowed by the Ray and its tributaries when the volume of water is too great for the narrow gap at Islip.

Much of the alluvium shown in the map, *e.g.* between Islip and Kidlington, is above the present flood-level; it is probably somewhat older, but generally no line of division can be drawn between it and the more recent flood deposits. The village of Murcot stands above the level of Ot Moor, but is built upon sand and silt of fluviatile origin. On the south side of Ot Moor the alluvium extends up the slopes, and thins out so gradually that it is impossible to fix its boundary with accuracy. Calcareous tufa coating fragments of fossils and small branches of trees may frequently be seen in the springs thrown out below the Corallian rocks near here, and Mr. Woodward has observed an instance north of Holton Wood.

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[1] *Quart. Journ. Geol. Soc.*, **xxxvi., 1880, p. 319.**

Close to the present courses of the rivers the alluvium is often at a slightly higher level than it is at some distance away, owing to the sudden check in the velocity of the stream as it overflows its banks, and the consequent deposition of part of the mud in suspension. This is well seen in the walks of *Mesopotamia*, where, during partial floods, a strip of meadow-land along the margin of the Cherwell is left dry when the rest is under water.

RIVER GRAVELS.

The older alluvia of the Thames in this region occur in terraces on the valley-slopes up to a height of nearly 100 feet above the present water-level. They consist of pebbles and small pieces of limestone from the Oolitic uplands, together with a variable quantity of quartzose and flinty material, probably washed out of the Glacial drift, which will be described further on. The pebbles are, as a rule, one or two inches across, and are well worn. The deposits are clearly stratified, and contain subordinate layers of sand and loam. Further down the river valley the oolitic pebbles, on account of attrition, diminish in number, and flints become the principal constituent; but the change does not take place within the limits of our region, although signs of transition are apparent towards the south.

There are four terraces in the Oxford district, of which the highest has not hitherto been found to contain fossil remains. The other three, which together constitute the low-level group, not rising more than about 50 feet above the present rivers, contain bones and teeth of mammoth, *Elephas antiquus*, woolly rhinoceros, hippopotamus and other mammalia, a good number of land and fresh-water shells of existing species, and flint implements which have been compared by Prof. Sollas to the early Palæolithic or "Chelléen" stage of culture.[1] Hence it is apparent that the river gravels are separated by a considerable interval of time from the recent alluvium.

First Terrace.

The youngest of the river gravels forms in some places a well-marked terrace five to ten feet above the level of flood; in others it occurs as insulated patches, surrounded by alluvium, and within the tract of floods. The surface follows the river valley with a more uniform gradient than the alluvium, being about 220 feet above the sea-level in the extreme west of the district, near Shifford, and 180 feet at Abingdon. Owing to the distribution of the alluvium in flat expanses at different levels, the gravel is sometimes completely overlapped.

In the western part of the district a terrace, five to ten feet above the alluvium, spreads from Shifford to Stanton Harcourt with two breaks, cut by a small stream near the former village, and by the Windrush at Standlake. A section near New Shifford Farm showed four feet of oolitic gravel on Oxford Clay. Elsewhere the gravel is seen in numerous dykes, but there are no openings showing its full thickness. At the hamlet of Moorton, near the river, the gravel rises in a low bank surrounded by alluvium on all sides and covered during the highest floods. It is said to be cemented into a hard rock. On the opposite side of the river, at Bablock Hythe, it is exposed to a depth of four feet in a shallow pit by the roadside. At Stanton Harcourt the gravel passes under the broad spread of alluvium and does not come to the surface again for several miles, but it can occasionally be seen in the rivulets which cut through the flood-loam. Small banks rise to the surface within the flood-tract near Eynsham, at Lower Wolvercot, Binsey, and on towards Oxford, where the gravel forms the foundation of the low-lying quarter near Folly Bridge and the suburb of New Hinksey. At the City Brewery it extends to a depth of thirty feet. South of the city the river has cut through the gravel to a somewhat greater depth, and it again appears as a terrace along the margin of the alluvium. A small pit by North Hinksey showed seven feet of oolitic gravel under two or three feet of loam. At another pit in South Hinksey the gravel was said to be ten feet thick. On the opposite bank, half a mile north of Iffley, gravel, probably of the same age, has been worked for many years. Teeth of mammoth and woolly rhinoceros have been found here, as well as a number of palæolithic implements, described by Mr. A. Montgomerie Bell.[1] The section is as follows:—

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[1] Remarks on paper by A. M. Bell in *Quart. Journ. Geol. Soc.*, vol. lx., 1904, pp. 131–2.

Loam	2 feet.
Oolitic gravel with seams of sand	8 „

According to information respecting the subsoil, there appears to be an outcrop of Oxford Clay between this pit and the somewhat higher gravel at Cowley. As the latter corresponds very well with the second terrace of Oxford, the isolated patch here described is most probably the first terrace.

Passing through the Sandford Gap the gravel is lost for some distance, but it reappears in the meadows at Radley and extends continuously as a well-marked terrace six feet higher than the alluvium to the east of Abingdon, where it is cut through by a small tributary. The same terrace forms the foundations of the lower part of the town and the opposite bank of the River Ock, and also occurs within the alluvial tract on Andersey Island. Sections are shown in a few pits, for the most part disused, *e.g.* close to the river a quarter of a mile south-east of Radley Village, where the gravel is dug to a depth of three feet under a loamy soil one foot thick. In other places six feet or more of gravel can be seen.

The banks against which the gravel was laid are, for the most part, intact, and the present channel does not differ greatly from the old. But an exception may be observed at Shifford, in the extreme west of district, where the river now flows through a valley a mile long between banks of Oxford Clay, and the old channel filled with gravel lies farther north in a direct line between Standlake and Bampton. This is one of many instances in which, during the progress of denudation, the course of the river has become more tortuous.

Second Terrace.

The second gravel occurs as a well-marked terrace through nearly the whole length of the Thames Valley, and is by far the most extensive, since it is less denuded than the older terraces, and is nowhere overlapped by the recent alluvium like the newer terrace. In this region it is from 20 to

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[1] *Quart. Journ. Geol. Soc.*, lx., 1904, p. 120.

30 feet above the river. It is this terrace upon which Oxford and most of the villages of the Upper Thames Valley are built.

Beginning in the west, the rise of the terrace is very conspicuous north of Brighthampton and Standlake, and up the right bank of the Windrush as far as Cokethorpe Park. The gravel is exposed in pits by the site of the British Village, and at the cross-roads close to Hardwick. At the former it is at least 12 feet thick, and consists of oolitic pebbles, one or two inches in length, with a considerable number of quartzites and other erratics. Along the bank of the Windrush the base of the gravel can be easily traced by small springs thrown out at the surface of the subjacent Oxford Clay. Close to Brighthampton, also, there is a spring showing that the gravel rests on a platform of clay, above the level of the adjacent low terrace. On the left bank of the Windrush a corresponding terrace extends nearly three miles in the parish of Stanton Harcourt. It has been opened in numerous pits, now for the most part disused, which show as much as 9 feet of gravel without reaching the bottom. Near the village the gravel is cemented with iron into a rock hard enough to be used for building. The cemented layer, which is a foot or two thick, lies not far below the surface soil, and can still be seen in an old pit S.W. of the village. The walls of the Norman nave of the church at Stanton Harcourt are built of rough blocks of this material, many of which, after nearly 800 years of exposure, show little sign of decay.

Monoliths of the same rock, six to eight feet high, have been set up in the fields south-west of the church, and are known as the "devil's quoits." Further north the terrace is cut through in two places by branches of the Limb Brook and by the Chil Brook, but with these exceptions it is continuous to the mouth of the Evenlode. Well-sections near Eynsham show considerable variation in the thickness of the gravel. Near the railway-station, probably the thickest part, four measurements gave 14 ft., 14 ft., 15 ft. 8 in., and 21 ft. respectively. At Newfield Cottage, nearer the landward margin, the thickness was only seven feet, while near the edge towards the river five feet and seven feet respectively were recorded.[1] Excepting a few short breaks this gravel extends three miles up the right bank of the Evenlode to Hanborough railway-station, near which it is exposed in several old pits, but it is only a few feet thick and the terrace is not more than a quarter of a mile wide. Returning to the main valley there are three patches of the second terrace at Cassington and Worton, separated by small brooks. In a pit near Cassington Mill the gravel was seen to consist of small pebbles of Great Oolite, Forest Marble and Cornbrash, with a few quartzites of various kinds. Between Worton and Yarnton the Thames has cut back the gravel so that the flood-plain extends to the clay slope beyond, but the terrace reappears at the latter village near the debouchment of the Cherwell at this epoch. In the pits by the railway-station the gravel is from twelve to sixteen feet thick, but only the upper part is now exposed. It was stated by Phillips to be "formed of many irregular, mostly undulated layers of gravel and sand with stripes of clay; the stones, mostly oolitic, with admixture of flints, red grits, and white quartz. . . . . It yielded at and near the bottom, where large pebbles of Northern drift formed an almost solid bed, a profusion of teeth and tusks of *Elephas primigenius*."[2] In the corresponding terrace on the opposite bank of the Thames under the brow of Wytham Hill, remains of ox, deer, *Elephas antiquus*, *E. primigenius*, *Rhinoceros tichorhinus* [= *R. antiquitatis* Blum.], *Equus caballus*, *Hippopotamus major*, and *Sus scrofa* have been found.[1] An old pit by Wytham Mill and two others north-west and south-west of Northfield Farm respectively, showed sections of about six feet of gravel consisting mainly of Corallian rocks, with some quartzites, quartz pebbles, lydite, derived fragments of *Ostrea*, and a very few flints. In the second of the two pits the gravel is cemented in layers by carbonate of lime.[2] North of Yarnton detached areas of the same terrace can be traced up the former course of the Cherwell to Kidlington. In the railway-cutting south of the station the gravel is at least twelve feet thick and is mainly oolitic. In an old pit close by, it contains thin clay bands which have yielded a few land and fresh-water shells[3] of existing species. *Corbicula fluminalis* has also been found in gravel near Kidlington, and remains of *Rhinoceros antiquitatis*.

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[1] From the notes of J. H. Blake.

[2] Geology of Oxford and the Valley of the Thames, p. 463.

Returning to the Thames Valley, small remnants of the second terrace are found on the right bank near Binsey, and at Botley. On the left bank is the long spread of gravel stretching from Summertown to Oxford, and occupying nearly the whole space between the Thames and Cherwell. The best section is at the brick-kilns on the Woodstock road, near Summertown, which showed:—

Soil	2 feet.
Gravel	3 „
Sand	2 „
Gravel	4 „
Oxford Clay seen to depth of	40 „

Another pit near the bridge over the canal in Heyfield Lane showed 8 feet of gravel. It is also frequently exposed in making the foundations of new houses in the northern part of Oxford. It is composed of small oolitic pebbles, with quartzites and other erratics derived from the Northern drift, and is usually covered by an irregular layer of brown loam, mainly due to the weathering of the surface and dissolution of the calcareous matter. Prestwich[4] described the following section exposed in digging the foundations for new buildings at St. Edward's School, Summertown:—

	Ft	in.
Soil	1	0
Fine gravel (with irregular black and ferruginous veins)	3	2
Yellow sand, with land and fresh-water shells (*Corbicula fluminalis*)	3	6
Sand	3	0
Hard Gravel.		

In Oxford itself there is more sand and clay. Along George Street and Abbot Road, the subsoil is nearly all laminated sandy clay, stiff and impermeable, but at the corner of Grove Street in George Street, there is five feet of clean gravel. At the top of Walton Crescent nine feet of gravel were seen under four feet of soil and made ground.[5] Pits showing a few feet of gravel are also seen by Holywell Cemetery and in the University Park. The upper surface of the gravel is almost a dead level (210 feet above O.D.) from Summertown to Broad Street. Carfax is higher having probably been artificially raised. But on either side the terrace inclines gently towards the Cherwell and the Thames. The platform of clay underneath the gravel is shown by wells and foundations of houses to have an uneven surface[1] (see p. 90). Thus, near the brickworks at Summertown the full thickness of gravel is 15 feet, at Summer Villa 9 feet, North Cottage 6 feet, Blackhall Farm 4 feet to 6 feet, Bardwell Road 9 feet. In some places the Oxford Clay comes nearly to the surface, in others water is reached at a small depth in gravel, apparently held up in a hollow in the clay. At others again there is no water till the base of the gravel is reached. On the whole the gravel is thinner and cleaner in North Oxford and is bounded by banks of clay which throw out the water into the Thames and Cherwell. In the older part of the city there is more clay in the gravel, which, by preventing rain water from percolating freely through, increases the muddiness of the streets in wet weather, and is conducive to thick fogs.

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[1] Phillips, *op. cit.*, p. 474.
[2] From the notes of J. H. Blake.
[3] Phillips, *op. cit.*, p. 464.
[4] *Geol. Mag.*, 1882, p. 49.
[5] From the notes of Prof. A. H. Green.

The base of the Oxford gravel crops out about half-way down St. Aldates, and the lower gravel comes on almost immediately. There may be an outcrop of Oxford Clay between the two terraces near the bottom of the hill, but there were no openings to show this at the time of the survey. In the low-lying parts near Folly Bridge gravel has been observed under several of the streets.[2] The gravel at Oxford has yielded remains of *Bos primigenius*, *Elephas primigenius*, *Equus caballus*, *Felis leo* (var. *spelæa*), *Rhinoceros antiquitatis*, and a large dog or wolf. The occurrence of reindeer in the Oxford district has also been recorded by Prestwich.[3] On the east bank of the Cherwell are three patches of the second terrace at Marston Farm, Marston Village and Cowley St. John. The first shows no sections; in the second the gravel is about eight feet thick at a pond near the footpath to the ferry, and consists of rag, fragments of *Ostrea* and *Gryphæa*, flint, quartz, quartzite, and ironstone. At Cowley the gravel is much thinner than in Oxford, owing probably to the proximity of the river-bank. Pits have been dug near the Iffley Road by Victoria Cottage and at the end of the lane by Fairacres House. Gravel has also been exposed in some of the streets: —

	Feet.
By Iffley Road near James Street	7
At the corner of Bullingdon Road and Denmark Street	3
„ „ Hurst Street and Leopold Street ...	6
At Fairacres House[4]	5

Beyond Cowley the second terrace is not seen again till the river reaches the outcrop of the Kimeridge Clay south of the gap at Sandford. Three small patches separated by tributary streams extend along the right bank to Radley, but these show no sections. On the concave side of the bend between Radley and Abingdon the terrace widens to the extent of a mile, and has been opened in numerous pits, which show gravel of the same general character as in the upper reaches of the valley, viz., small and oolitic with an admixture of quartzites and flints, occasionally cemented into a rock. The abundance of fragments from the neighbouring Corallian rocks and some from concretions in the Kimeridge Clay should be observed. At a pit just outside Abingdon on the Faringdon road is the following section[5]:—

	Ft.	in.
Mould	1	0
Gravel with lenticular patches of sand	6	0
Clay	1	3
Coarse gravel with bones	4	0

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[1] This was noted by the Rev. J. C. Clutterbuck, *Journ. R. Agric. Soc.*, ser. 2, i., 1865, p. 278.

[2] From the notes of J. H. Blake.

[3] *Geol. Mag.*, 1882, p. 51.

[4] From the notes of J. H. Blake.

[5] *Ibid.*

The terrace extends a short way into the valley of the Ock west of the town till it is cut off by a tributary from the north. Remains of *Bos primigenius* have been obtained at Abingdon, probably from the second terrace.

The old banks against which this gravel was laid have been very largely destroyed by later denudation. In the curve between Brighthampton and Wytham, the Thames eroded a new channel on the convex side or right-hand bank. The same thing has happened on the left bank between Sandford and Abingdon. Not only has denudation been effected by the main river, but small brooks descending the slopes of clay have cut channels along the inner margin of the terrace and broken it up into a series of peninsulas and islands in the alluvial plain. Occasionally, for short distances, the river banks remain, as for instance to the north of Summertown, and again between Radley and Abingdon. More often the gravels are completely detached, as at Marston, where a broad strip of alluvial meadow separates the terrace from the slopes of Elsfield.

The changes in the courses of the rivers since the epoch of the second terrace have not been very great, the most important being in the case of the Cherwell, which at that time flowed directly into the Thames near Yarnton. The mouth of the Evenlode was near Eynsham, that of the Windrush not far from the old British Village near Standlake. The Ray joined the Thames about Summertown, the gravels of Oxford and Marston forming one continuous deposit laid down by the two rivers combined.

Third Terrace.

The third terrace of the Thames Valley is only found in a few places in the Oxford district, owing to the extent of subsequent denudation. (See Fig. 12.) The most interesting remnant is at Wolvercot, at the top of a plateau three-quarters of a mile in area, between the present courses of the Thames and Cherwell, and forty or fifty feet above their present levels. Near where the Woodstock road crosses the North-Western Railway, is a brick-pit showing the fluviatile deposits above the Oxford Clay, and they have been described in detail by Mr. A. M. Bell,[2] who has collected from them a large number of flint implements and plant-remains.

The river deposits are as follows:—

		Ft.	in.
River Gravel	Finely laminated clay	15	0
	Lenticle of peat and sand	0	2
	Gravel and sand	2	6
Oxford Clay			

The gravel at the base is current-bedded and contains numerous quartzite and sandstone pebbles, generally small, but occasionally as much as 2 feet square. It rests on a somewhat uneven surface of Oxford Clay. The bed is rich in palæolithic implements and in mammalian remains. In the words of Mr. Bell:—"The implements are formed of flint taken freshly

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[1] Phillips, *op. cit.*, p. 474.

[2] *Quart. Journ. Geol. Soc.*, vol. lx., 1904, pp. 120-132.

from the Chalk, or of quartzite-pebbles of the Northern Drift, and they are remarkable for their size, beauty, and freshness. As usual, they have a facies of their own; the oval type is rare, and the pointed examples are very frequently flat or nearly so on one side, belonging to what Sir John Evans has named the 'shoe-shaped' type." The mammalian remains include *Elephas primigenius, Equus caballus, Bos primigenius, Cervus elaphus,* and *Rangifer tarandus.* Eleven species of fluviatile shells were obtained from the sand included in the gravel bed. The peat-bed which lies on the gravel has yielded 30 species of flowering plants and 35 or 37 of mosses. It is described by Mr. C. Reid as a water-surface, which had caught and deposited in a back-water a number of plant-remains floated down the stream. About two-thirds of the mosses, as well as the flowering plants, are still found in the neighbourhood. But some of the others are exceptional. Thus *Hypnum capillifolium,* Warnst, has only been found in Britain in the arctic freshwater bed at Mundesley, and now occurs in high northern latitudes. *Thuidium decipiens,* De Not, is an Alpine species found in the Scottish Highlands but not elsewhere in this country. Five others, *Camptothecium nitens,* Schp., *Dichodontium pellucidum,* Schp., *Hypnum giganteum,* Schp, *H. revolvens,* Sow., *H. stramineum,* Dicks, are sub-Alpine, not now living in Oxfordshire.[1]

The 15 feet of laminated clay above the peat have yielded no determinable fossils. "They are conformable to the gravel below and have been laid down by water, as is manifest from the long and even lines of deposition. But there is no gravel and little sand, only successive layers of mud and clay—sometimes blue Oxford Clay, very little altered, at others the layers are coloured yellow and red by the oxidation of iron. The whole upper part has the appearance of having been laid down in a lake, or in a large river-pool, but not in a running stream such as deposited the gravel."

On the west side of the pit near the railway the bedded loam thins away, and the Oxford Clay rises within a few feet of the top. Here there is an unstratified gravel consisting of quartzose pebbles with a few of Oolite in holes in the Oxford Clay. At another brick-pit on Peartree Hill three-quarters of a mile further on towards Woodstock, a very similar deposit may be seen, the gravel there containing some large stones a foot in diameter, though the greater number do not exceed two inches. Many weather-worn fragments of flint, seemingly derived from older deposits, may be found, and a few also which appear fresh and unbroken. From the amorphous gravel of both these pits Mr. Bell has obtained rude palæolithic implements, which from their weathered character he infers to belong to an earlier epoch than those from beneath the loam at Wolvercot. The southern part of the plateau consists of Oolitic gravel like the lower terraces.

At a pit a quarter of a mile S.E. of the railway bridge, on the Woodstock road, there was 7 feet of small Oolitic gravel exposed, with boulders from the drift near the bottom. Two other pits, much overgrown, one opposite the gate of the cemetery on the Banbury road, and the other a quarter of a mile nearer Oxford, showed Oolitic gravel considerably smaller than that of the other terraces. The laminated clay, which is thus restricted to the north part of the plateau at Wolvercot, has been laid down in a hollow eroded through gravel into the Oxford Clay, and the surface has subsequently undergone disturbance which has been attributed to the passage of ice.[2]

This explanation, however, appears open to doubt. The amorphous gravel at the side of the pit, containing a mixture of quartzose and Oolitic fragments, is just such a deposit as might be formed by decalcification of a river-gravel and obliteration of the lines of bedding. The peculiar way in which both the gravel and the loam are inserted in hollows in the Oxford Clay may be due to underground erosion and consequent subsidence of portions of the clay over the fluviatile deposits.[1] Perhaps frosts of greater severity than now occur have aided in breaking up the ground, but the hypothesis of glaciation in the Thames Valley at this stage of its development, even if probable on other grounds, seems unnecessary to explain the appearances in this pit. The true drift of this region belongs, as will be shown later, to an earlier stage in the erosion of the valley.

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[1] The mosses were determined by Messrs. A. Gepp and H. N. Dixon, the flowering plants by Mr. C. Reid.

[2] A. M. Bell, *Quart. Journ. Geol. Soc.*, lx., p. 127.

The deposits of the Wolvercot plateau and Peartree Hill are completely isolated by denudation from all other remnants of the same terrace. But four miles further north, near where the Cherwell emerges from the narrow valley in the Lower Oolite Limestones, there is a loamy deposit with abundant quartzose pebbles extending over an area rather more than half a mile square, and occupying the position of the third terrace; but there are no sections. On the opposite side of a small brook at the foot of Bladon Heath, small remnants of the same terrace, with the gravel partially cemented by iron, extend in a north-westerly direction towards the Glyme, in such a way as to indicate that that river was at the time a tributary of the Cherwell, instead of the Evenlode. The Evenlode itself appears to have followed the gap, through which the railway passes between Yarnton and Hanborough. A remnant of gravel, consisting of oolite and quartzite pebbles, seems to have been worked at one time where the road from Cassington to Bladon crosses the railway. Other patches of the same terrace occur on the north side of Burleigh Wood, in the valley of the Evenlode, and in Blenheim Park, on the narrow neck of land separating that river from the Glyme. In the upper part of the Thames Valley no rudiments of the third terrace have been found.

Below the Sandford gap the third terrace reappears in two outliers on Kimeridge Clay along the road south of Radley Wood. Gravel has been worked there, and also by the roadside near the Radley College gates, where it is cemented into a hard rock. A pit close to the cross-roads S.E. of Radley Wood was open at the time of the survey to a depth of six feet. The gravel consists of Oolitic fragments, among which Coral Rag is abundant, and siliceous pebbles derived from the drift, of about the same size as those at Wolvercot, but smaller than those in the lower terraces. On the west side the Kimeridge Clay rises abruptly from beneath the third terrace to the level of the fourth in the grounds of Radley College. On the south and east there is a more gradual but still conspicuous fall of the surface to the plain of the second terrace between Radley and Abingdon.

Fourth Terrace.

The gravels hitherto described may be classed as the low-level group. Between them and the next older there was a very marked epoch of erosion, during which the Thames cut down its valley to the extent of about 50 feet. The higher gravel, which is principally developed in the upper valley, crowns a series of promontories projecting from the uplands in the N.W. on to the plane of the low terraces. Within the limits of the map the height above the present rivers varies from 70 feet to 100 feet. Between the Windrush and Thames Valleys there is an irregular outlier on the hill west of Hardwick. A few old gravel pits with Oolitic pebbles may be seen, but no good sections. On the opposite side of the Windrush are two small patches at High Cogges, and another west of Tar Wood. The most westerly of these, that at Spring Hill, was exposed in a small pit at the time of the survey. The gravel is composed principally of small oolitic pebbles, with quartzose pebbles from the Northern drift, thus resembling the gravel of the low terraces. The next outlier is at South Leigh, where there is a small pit in which the gravel contains numerous siliceous pebbles at the top and appears disturbed at the surface, as is commonly the case in terraces at all levels. Lower down the valley there is a gravelly soil at the top of a hill N.W. of the village of Eynsham. The pebbles are all from the drift, but it seems probable that this is a remnant of the fourth terrace from which the calcareous constituents have decayed away.

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[1] See also H. B. Woodward on Underground Waste of the Land, *Nat. Science*, 1893, p. 126.

The largest remnant of this terrace is that on which the villages of Church Hanborough and Long Hanborough are built. There are numerous pits, 12 feet deep or more, the best of which is at "The Row," Long Hanborough.[1] The gravel is well-bedded, consisting of Oolite and quartzite pebbles an inch or two in diameter. At the top is a layer of brown loam of irregular thickness containing numerous quartzites, and descending in pipes to the bottom of the pit. This is evidently due to the weathering of the surface and consequent dissolution of the calcareous material by rain-water. The top of the terrace rises from a little over 300 feet at Church Hanborough to 330 at Long Hanborough, more than 90 feet above the Evenlode. In the village street at Church Hanborough, and in an old pit to the north, this gravel may be seen cemented into a rock by carbonate of lime.

On the opposite side of the river, facing Church Hanborough, the gravel is found again on a small plateau by Purwell Farm at a height of about 300 feet. A section in an old pit showed the constituents to be mainly pebbles of Great Oolite, about an inch in length, but with Forest Marble and Cornbrash in considerable quantity. Some of the layers were coarser, with fragments three inches in length. There were also many pebbles of quartzite and small worn flint fragments.

The last of the remnants of the fourth terrace in this part of the valley is north-west of Yarnton. There is a larger proportion of quartzites here, due, probably, to the more advanced state of weathering. In a pit on the south-west side of the lane leading from Yarnton towards Begbroke Wood six feet of gravel were seen, of which the upper three feet consisted of a weathered residue of siliceous pebbles in brown loam, the rest being normal Oolitic gravel. This is the last trace of the fourth terrace till the tract of Kimeridge Clay south of the Sandford gap is reached. Between Kennington and Radley there is a terrace between 80 and 90 feet above the river, breached in two places by rivulets from Boars Hill. In an old pit near the gate of the golf course (opposite Sandford Pool) the deposit was seen to be mainly quartzose gravel and flints, embedded in sand derived from the Ironsands of Boars Hill. It is not easy here to separate river gravel from high-level drift; but at Radley the abundance of Oolitic pebbles on the surface of the terrace indicates a fluviatile origin. At a well sunk recently at the College the gravel was found to be eight feet thick.

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[1] See E. Hull, Geology of the country around Woodstock, *Mem. Geol. Surv.*, 1859, p. 28; and A. E. Salter, *Proc. Geol. Assoc.*, xix., 1905, p. 39.

The difference in elevation of the high terraces at Yarnton and Radley is over 40 feet, though the river falls only 30 feet between these points. There is, however, little doubt that the terraces are contemporaneous, and the discrepancy may be due to the slower rate of erosion at the gap in the Corallian escarpment which is not far above Radley. The high terrace here is at about the same distance above the river as that at Standlake. Beyond Radley no more of the fourth terrace is seen within the limits of the map.

Other Alluvial Terraces.

We may now turn to the alluvial terraces of the other river valleys of our region.

Above Long Hanborough the Evenlode flows for several miles through a winding gorge cut in the hard Oolitic Limestones; and though there is a strip of alluvial meadow along the margin of the river, few traces of gravel are to be seen. Towards Ashford Mill, however, faintly-marked platforms make their appearance in the side of the gorge, occupying the position of the fourth terrace, and high up on the right bank of the river N.E. of Wilcote a small outlier of the gravel was shown in an old pit.

Wilcote Valley.—From this point a cross-valley runs westward between the villages of Wilcote and North Leigh to the Windrush beyond Witney. At the time of the fourth terrace this valley contained a river of considerable volume, which has since been diverted. Small outliers of gravel can be traced at different points from the Evenlode to North Leigh and westward to the margin of the area. Two pits were seen, a quarter of a mile W.N.W. and half a mile S.E. respectively of Holly Court Farm, showing bedded gravel of the usual composition, viz., pebbles and small tabular pieces of Oolite, together with siliceous pebbles from the northern drift. In the latter pit there is a layer at the surface, a few feet thick, of loam and quartzites, formed by weathering.

In the graveyard of North Leigh Church there is more than seven feet of gravel consisting very largely of quartzites. Here, also, the terracing of the river deposit against curving banks of limestone is most conspicuous. The gravels rise slightly in level from the Evenlode westward, showing clearly the direction of the water-flow.

The river was one of considerable magnitude, and may perhaps have been the Windrush itself. Now in the Thames Valley, at High Cogges, near the present course of the Windrush, the fourth terrace is at a much lower level. It is possible, therefore, that the tributaries of the Thames in this quarter had cut so far back that the old Wilcote river found a quicker descent into the main river than by following its own valley into the Evenlode, and thus came to be diverted. Further investigation of the tract west of Witney will probably throw light on the history of these rivers.

Ray Valley.—There is a considerable extent of gravel of the first terrace east of Islip, which has been brought by tributaries of the Ray from the Oolite uplands to the north. Small exposures may be seen by field ponds and along brook beds, which indicate that the gravel is only a few feet thick. No higher terraces are seen, nor is any conspicuous development of them to be expected in the upper part of the valley beyond the limits of the map, as the tributaries of the Ray which traverse the Oolitic strata, are small streams, and those from other directions flow through a clay country.

It is worthy of notice, however, that the Great Oolite inlier at Islip is cut into rude platforms, which rise one above another on the left bank of the river, and appear to be independent of the structure of the strata. It is possible that these are rock-ledges formed by the Ray, corresponding to the gravel terraces elsewhere.

Thame Valley.—The Thame joins the Thames at Dorchester beyond the southern edge of the area shown on the map, but there are extensive tracts of gravel overspreading the Gault south of Chislehampton which were laid down at the confluence of the two rivers in the Pleistocene period. Here, as in the upper reaches of its valley, the Thames has step by step shifted its course to the southward. A succession of alluvia of different ages may be traced similar to that which has been already described. Close to the Thame itself is the flood plain, formed of silt, from an eighth to a quarter of a mile in breadth, but as much as half a mile at several points between Wheatley and the town of Thame. Next comes the lowest gravel terrace, which at Drayton St. Leonard extends a mile from the present river, five or six feet above the flood plain. The best section of this gravel was seen close to the Thames at Burcot, just beyond the map, where it is made up principally of fragments of brown Oolitic limestone, hard Chalk, gritty limestone, quartz, quartzite, flints (rounded and subangular), and probably Upper Greensand, nearly all less than an inch in diameter.[1] The full thickness of the deposit was not known, as it extends below the level of the river.

The second terrace rises with a well-marked feature 20 to 30 feet above the lowest, and an outcrop of Gault separates them most of the way. It is cut through in several places by streams flowing from the Portland Beds of March Baldon, and emptying into the Thame near Chislehampton and the Thames near Burcot.

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[1] See also note by J. H. Blake, Summary of Progress for 1900, *Mem. Geol. Survey*, 1901, p. 130.

A pit two-thirds of a mile S.W. of Chislehampton showed five feet of small false-bedded gravel consisting mostly of Oolitic Limestone pebbles, among which were found pieces of the Great Oolite white limestone. There was also a large number of lydites, a few quartzites, white quartz pebbles, flints and pieces of ironstone.[1] Other pits south of Field Farm near the Roman Way showed similar sections. The gravel is weathered to a depth of several feet in places, notably so at a pit rather more than half a mile north of Field Farm, where there is an excess of siliceous pebbles due to the dissolution of the limestone constituents.

The gravels here described were probably due more to the Upper Thames than to the Thame. The presence of Chalk and other Cretaceous fragments shows that the transition from the Oolite gravels of the upper valley to the flint gravel of the Lower Thames had already begun. Some of the feeders of the river rise in the Chalk downs of Berkshire, south of the vale of the "White Horse," and this must have been the source from which the Chalk and Greensand pebbles at Burcot were brought. But the Oolite limestone is still a dominant constituent, and it is not till Dorchester is passed that its place is taken by flint.

There are no sections of gravels higher than the second terrace in the region near the mouth of the Thame. There is a third terrace rising with a good feature 15 or 20 feet above the second and extending from Burcot Farm a mile and a half to the north-east; but except at the farm itself, where the Greensand crops out between them, it is difficult to separate the gravels of the two terraces. If the top of the Greensand be traced up the brooks from Burcot, a conspicuous rise in level may be noticed on passing from the second to the third terrace near the 200-foot contour line, but there is not sufficient evidence to show that there is any outcrop of Greensand between the two. Thus it cannot be proved that the feature just mentioned is any more than a ledge cut by the river in a continuous bed of gravel, although, taken in connection with the evidence at Wolvercot and Radley, it is probable that there are here two beds overlapping, which were formed at successive stages in the development of the river valley.

The patch of gravel S.W. of Chislehampton is noticeable on account of the cone-shaped hill in the middle. On the side near the Thame is a pit showing gravel of the second terrace. The conical hill, which appears also to be gravel, though there is no section, is probably a denuded remnant of the third terrace, cut partly by the Thame and partly by the Baldon Brook.

At the cross-roads at "Golden Balls," south of March Baldon, on Clifton Heath to the S.W., and $\frac{1}{4}$ mile to N.W., are four patches of gravel which correspond approximately to the fourth terrace, but they are small remnants which show no sections, so that it is uncertain whether they are river gravels or older plateau drift.

On the opposite side of the Thame between Stadhampton and Chalgrove is a plateau of gravel, nearly three miles long, corresponding in level to the third terrace. A smaller area of gravel at Little Haseley, on the north side of the Haseley Brook, is probably a detached part of the same plateau. No good section was observed, but at an overgrown pit (by the "R" of Rofford) the gravel mainly consists of chalk flints, angular, subangular or rounded; and since the surface rises 35 feet towards the Chiltern escarpment, it was most probably laid down by a river coming from that direction. There are now two tributaries, one on each side of the plateau—the Great Haseley and the Chalgrove Brooks—which rise in the Chalk hills, but these two combined seem scarcely large enough to have formed a bed of gravel comparable in extent and thickness with that of the Thames itself. It is possible that the gravel marks an old channel of the Thame more direct than the present circuitous course east of the Shotover Hills. Its wide extent and the unworn state of many of the flints are suggestive of the proximity of melting ice-fields, but, until the country between here and Aylesbury is more fully investigated, glaciation at so late a period in the erosion of the Thames Valley in this district must be considered as doubtful.

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[1] From the notes of J. H. Blake.

In the upper part of the Thame Valley, east of the Shotover range, the gravels are much less conspicuous. They differ from those of the Thames in the absence of Oolitic Limestone pebbles, their place being taken by flints and quartzose pebbles derived from the drift. The Thame does not drain any part of the country of the Lower Oolites, but outliers of Portland Beds lie within its basin. Some of the tributaries may have brought flints directly from the Chilterns, but the principal source of the constituents in the gravel was no doubt the drift which once spread over the whole valley, but is now confined to a few outliers, such as that which covers the plateau south of Tiddington. This drift in the main consists of flints, but there is an admixture of pebbles of quartz and quartzite derived from Northern sources.

The composition of the low level gravels is similar, but many of the flints are more water-worn. Near Little Milton there are one or two small patches of gravel belonging to the two lowest terraces. Higher up, near the bend of the river east of Wheatley, is a strip along the left bank one-third of a mile long belonging to the second terrace.

The following notes are by Mr. Woodward:—

An extensive tract of gravel of the same age occurs over the south and east of Waterstock, banked up to a certain extent against the Kimeridge Clay on the south. The gravel is composed of subangular flints and pebbles of flint, quartz and quartzite. A thickness of 10 feet was opened up (base not seen) to the south of Draycot, and a little to the south-east of the junction with the lane leading to Waterstock.

In the parishes of Ickford, Worminghall and Waterperry there are occasional thin and irregular gravelly coatings with flints and lydites; but no good gravel occurs, and that used for mending the paths west of the Church at Worminghall was brought from Cookham. By Parsons Farm, in Waterperry parish, there is a thin tract of fine sandy gravel resting on the Oxford Clay, and this yields limited supplies of water to the shallow wells. It may be a remnant of the third terrace.

[As mentioned on p. 99, two patches coloured as drift S.E. and S.W. of Waterstock, may be remnants of the fourth river terrace of the Thame. If they are drift there appears to be no representative of this terrace in the valley.]

On the right bank of the Thame below Holton Mill, and again south of the Great Western Railway bridge, there are thin cappings of gravel.

South and south-west of Waterperry House the clayey ground of the Corallian merges so gradually into the Alluvial ground that the geological boundary is vague. H. B. W.

PLATEAU DRIFT.

No river-gravels older than the fourth terrace are found in the Oxford district, but at elevations of 100 feet and upwards above the present rivers a different kind of deposit is met with, which has long been known by the name of "Northern Drift." It covers a small extent of superficial area, not because it was limited to the spots where it now occurs, but because broad river valleys have been excavated since it was formed, and a vast amount of denudation by lesser streams has removed the greater part of what once existed.

The drift is distinguished from the river gravels in several respects:—

> *First.* The constituent blocks are all, or nearly all, derived from regions beyond the present drainage areas of the rivers. Many of these have their edges worn smooth, but are not rounded, and though they rarely, if ever, show striæ, they resemble glacial detritus rather than pebbles from a river bed.
>
> *Secondly.* There is an absence of stratification characteristic of river alluvia.
>
> *Thirdly.* The drift passes up the old valley-slopes without regard to elevation, and is not restricted to terraces.

It is plain that neither the slow-flowing modern rivers nor their more vigorous precursors, which spread out the gravel terraces, can have given rise to the Northern Drift.

The most extensive area of the drift lies between the Evenlode and Windrush Valleys. Beginning from the river gravel at Hanborough, with which it appears to be in contact, it extends to the top of the hill at the north end of Eynsham Park, about 200 feet above the Evenlode. The patches on the map at North Leigh, New Yatt, and southward to High Cogges represent portions which have been detached by numerous small brooks from a once continuous mass of drift. They fall gradually in level till they almost reach the river gravel at High Cogges. Towards the north the drift is cut off abruptly by the steep slope of the Wilcote Valley; but it reappears on the opposite side in two little outliers, at Wilcote Village and an adjacent hill to the west. There are traces in the valley itself above the level of the river gravel, perhaps indicating that it was partly excavated before the drift.

The gorge of the Evenlode cuts off the drift at Long Hanborough from outliers at the top of Combe Hill, about a mile east of the village. Between the Evenlode and the Cherwell a similar deposit caps Bladon Heath, and extends downwards towards the high terrace above Yarnton.

Throughout this tract there are few sections, the clearest being at "The Demesnes" near North Leigh, where the stones are obtained for road-metal. The Oxford Clay in this pit consists of purplish shale below, with a layer of tough, somewhat pale green, clay above. On the top is an irregular bed of brown mottled loam, a few feet thick, full of stones set at all angles, penetrating the Oxford Clay in irregular hollows. The stones are a very mixed collection, among which occur numerous partially rounded flints a few inches across, and smaller fragments quite unworn. These have originally been derived from the Chalk, but they are so deeply weathered that it is probable that they had gone through more than one stage of transport and deposit before they reached their present position.

Other constituents are liver-coloured quartzites, doubtless from the Bunter Pebble beds of the Midland Counties, white vein quartz and variously coloured quartzites, probably from the same formation, hard sandstones resembling greywethers, also softer sandstones with felspar of the Millstone Grit type, and black lydian stone of unknown origin. The whole deposit of drift has the appearance of having been disturbed by the action of underground water. Many of these stones are subangular and may well have been worn by ice, but the extreme rarity if not entire absence of glacial striæ shows that the drift is not normal *moraine-profonde* though in all probability due to the action of ice. The section at the Combe brick-pit, which lies just beyond the edge of the map, is of similar character. There are also old gravel pits on Bladon Heath, but they show very little. At North Leigh and New Yatt there is a greater thickness of drift, and a gravel bed occurs at the base yielding a good supply of water. The numerous springs thrown out from the base of the drift have broken it up into a series of outliers separated by small valleys. At New Yatt a well was sunk through nine feet of clay and pebbles to a bed of gravel one foot thick, which yielded water. Towards the south, near the Hill Houses, the drift forms a stony clay soil, somewhat heavy, but much easier to plough than the adjacent Oxford Clay.

A part of the drift, which extends from the east of Eynsham Park by Freeland to Long Hanborough appears to form a terrace about 350 feet above the sea, and 120 feet above the river. There are no good sections, but a pond on the south side of the road from Freeland to Church Hanborough, 300 yards from the corner, showed three feet of pebbly loam resting on a foot of mottled sand. It is rudely bedded and may be a part of the drift which was sorted by water on what was then the bottom of the valley. But it is inseparable from the rest of the deposit and is most probably of the same epoch.

At lower levels in the Upper Thames Valley no drift is met with *in situ*, but the numerous siliceous pebbles found in the fluviatile gravels, and in all probability derived from the drift, indicate that this portion of the valley has been excavated at a subsequent period.

On the other side of the valley, drift is met with on Seacourt Hill, south of Wytham (see section at foot of the one-inch map). There are several overgrown pits, formerly worked for gravel: the constituents being chiefly quartzite, white quartz, and flint embedded in clay. The drift rests on the slope of the hill, about 270 feet above the river, but does not reach the top. The neighbouring hill of Wytham, which rises 80 feet higher, appears to be destitute of drift.

Cumnor Hill (or Hurst Hill), as has been mentioned before, is a detached eminence formed by an outlier of Ironsand, with small patches of Gault and drift, let into hollows at the surface. At the brick-pit there are two of these hollows which appear to be parts of a trench crossing the top of the hill from N.E. to S.W. The drift, which shows traces of stratification, is about twelve feet thick in the middle, where it rests on Gault clay, but it thins away at the sides, and overlaps on to the Ironsand. The stones are well-rounded or subangular, and consist of quartzose pebbles and flints, as in the drift on Seacourt Hill. The matrix contains reddish sand, derived from the Ironsand. Numerous smaller outliers on different parts of the hills, and at various levels, are shown by the abundance of pebbles in the soil at certain spots, and their complete absence elsewhere. Probably these outliers rest on small patches of Gault, while the adjacent Ironsand was not coherent enough to retain the drift.

The confusion of strata of different ages, which is so remarkable in the brick-pit, is probably due to several causes. In the first place the Kimeridge Clay, though less disturbed than the overlying formations, has its bedding arched, as is shown by the lines of concretions. This may be due to the earth movements which gave the strata their present structural forms, but something may have been effected by dissolution of the subjacent Corallian Limestone by underground waters. The Ironsand rests on a denuded arch of the clay in a way that is peculiarly favourable to landslips. Whenever the surface of the clay is wetted by the percolation of water, the overlying sand tends to slip down on both sides of the arch, and much of the material is carried away by the springs thrown out on the hillside. Fissures and hollows are thus formed into which the Gault clay subsided. The process, though still in operation, had gone on a considerable extent before the drift was deposited, for it has affected the gravel to a much less extent than the Gault. Some disturbing effect might also be expected from the action of the ice, and this has confidently been appealed to as the cause of all the anomalies,[1] but it is believed that the peculiar phenomena observed in the pit owe their origin in the main to the causes just described.[2]

On Chawley Hurst, a hill resembling Cumnor in form, and situated somewhat nearer Oxford, there is drift of the same kind. Probably it occurs in small patches, but this could not be determined. The highest outlier in the district is on Boars Hill, at a maximum elevation of 540 feet. A pit was newly opened at the time of the survey about 300 yards west of Picketts Heath Farm, showing eight feet of gravel and sand. The constituent pebbles were principally vein quartz, quartzite and flint, the last being much more abundant and in a fresher state than in the drift of the Evenlode.

A little to the north, another pit now disused showed much smaller gravel of the same materials, totally devoid of bedding, and having at the top an irregular layer about three feet thick of stiff grey clay. In the old pits at Picketts Heath Farm, where gravel has formerly been obtained in great quantity, there is also a clay bed which has been weathered yellow. The pebbly clay extends southward over the hill a little below the 500-foot contour, but is not connected with the drift at lower levels.

In Bagley Wood and Radley Park there are numerous patches of drift extending down the slopes from above the 400-foot contour line to below the 300-foot. Along the Oxford and Abingdon road through the wood, the drift was observed to contain pebbles of white quartz, quartzite, flint and lydite stone in reddish clay. In the pits by the roadside it seems to be at least ten feet thick and was probably worked for gravel. Buckland recorded igneous rocks from the drift here, which could have come from no nearer point than Charnwood Forest. At the top of the wood on the road to Boars Hill there was another obscure section showing pebbly clay.

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[1] F. A. Bather, *Journ. Oxford Junior Sci. Club*. 1887 (1888), p. 32.

[2] See diagrammatic section, Chawley Brick-pit, by Prof. W. J. Sollas, *Proc. Geol. Assoc.*, xix., 1905, p. 57; and remarks in discussion, *Quart. Journ. Geol. Soc.*, lx., p. 131.

A section was also open in the Sugwell Farm patch during the building of a house, which showed about four feet of drift on the Kimeridge Clay. It was of irregular thickness and unstratified. The matrix consisted of clay with a considerable quantity of sand derived from the neighbouring outcrop of Greensand. It was slightly permeable, so that water flowed from the base over the slope of Kimeridge Clay. At the same time it was sufficiently close-set to allow pools of water to stand on its surface. The pebbles consisted of white quartz, various quartzites, flint and lydite, but not limestone, On the opposite side of the river another group of outliers is found on high ground near the 300-foot contour-line in Nuneham Park. They rise to a height of 130 feet above the river and are much denuded. The drift consists of loam and clay full of rounded pebbles of quartzite, quartz, lydian stone and flint.[1] (See p. 79.)

In the basin of the Thame the composition of the drift is somewhat different. At the top of the hill N.W. of Chislehampton, at a height of 290 feet, 120 feet above the river, are two small patches of drift overlying Gault, in which flints are much more abundant, and the other constituents much less numerous in proportion. In the more southerly of the two patches a small pit was open three feet deep showing irregular gravel and loam much weathered. Mr. J. H. Blake ascertained that the deposit was as much as seven feet in depth at the farm-house close by.

The last of the remnants of drift to be described is one covering a plateau more than two miles in length, N.E. of Great Milton. Only one small pit was open at the time of the survey close to the high road, near Trindal's Farm. The gravel is essentially a mass of unworn flint fragments, without any arrangement. The common pebbles of the Northern drift are present but in subordinate quantity. According to Mr. J. H. Blake, the gravel "has been proved by well-sections to be from ten to twelve feet in thickness."[2]

The position of this mass of drift is a striking testimony to the vast denudation which has taken place since its formation. Standing on the plateau, the observer overlooks abrupt slopes on the north and west, leading to the river 150 feet below. On all sides numerous streams issuing at the surface of the Gault clay, underlying the drift, have cut their valleys far back into the plateau. To the south-east the broad Gault plain extends from Thame along the foot of the Greensand escarpment, where it might be thought would be an easier course for the river than the tortuous valley through the hills east of Shotover. That the whole depth of 150 feet has been eroded since the drift was formed must not be inferred, for it is possible that the gravel extended to lower levels, and that only the highest part has escaped denudation.

There are two smaller remnants of gravel, one near Tiddington Station, and the other a mile and a half down the river to the west, which are perhaps detached portions of the drift, but since they are at an elevation above the river corresponding to the high terrace of the Thames, they may prove to be river gravels of that epoch built up of drift materials. No sections were seen in either patch. (See p. 95.)

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[1] J. H. Blake, Summary of Progress for 1900, p. 130.
[2] Summary of Progress for 1898, *Mem. Geol. Survey*, 1899, p. 159.

Besides the drift that is shown on the map, abundance of erratic pebbles are found on the plateau west of Boars Hill; but Shotover Hill and the country east of the Cherwell appear to be destitute of drift, though clear traces are found at the top of Long Crendon Hill, near Thame (to the east of the area of the map), more than 400 feet above the sea.

The reason for this absence of drift is clear. The lowlands of Oxford Clay and Ampthill Clay, N.E. of Shotover, have been formed by denudation at a later period, and all traces of drift have been swept away, for neither water nor ice could have overflowed isolated summits such as Long Crendon and Boars Hill without leaving traces of its passage in the intervening hollows.

Sources and Nature of the Plateau Drift.

The phenomena of the drift in the vicinity of Oxford was one of the special subjects treated by Buckland in his "Reliquiæ Diluvianæ." Tracing the quartzose pebbles up the valleys of the Evenlode and Cherwell, he connected them with deposits near the heads of those rivers, containing white quartz, lydian stone, gneiss, igneous rocks, sandstones, Lias, chalk and flints, as well as the red quartzites, which he definitely recognised as belonging to the New Red Sandstone pebble-beds of the Midland Counties. Among the chalk pebbles he observed the red chalk of Lincolnshire and Yorkshire, and inferred that there had been a drift to the S.W. across the Midlands, which entered the Thames Valley by the gaps in the Oolite escarpment near the sources of the Evenlode and Cherwell. He further maintained that, since the drift is found at the tops of isolated hills such as Wytham and Cumnor, the valleys had been subsequently excavated.[1] Although the hypothesis of a northern "deluge" meets with little acceptance at the present day, there can be no doubt that many of the salient features in regard to the drift of this region, and the path by which the materials had been transported to their present positions, were clearly understood by Buckland in the first quarter of the 19th century.

Besides the valleys of the Evenlode and Cherwell, there were other sources of the drift. Thus red quartzose pebbles have been traced up the valley of the Windrush and northward by a gap near Stow-on-the-Wold, into the upper Evenlode Valley, and thence to the Vale of Moreton. Mr. H. J. Osborne White,[2] who has published a sketch map showing the distribution of the gravels with Triassic débris, found pebbles in the Coln Valley further west, and believed that they had been carried over the much higher gap in the Cotteswold Hills at the head of that river.

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[1] "Reliquiæ Diluvianæ" 1823, p. 250, *seq.*; Phillips, Geol. Oxford, &c., 1871, map p. 1, and p. 456.

[2] *Proc. Geol. Assoc.*, xv., 1897, p. 157.

Again, it was noticed on a previous page that the drift of the eastern part of the district consists mainly of flints. Even on Boars Hill the quantity much exceeds that of the Evenlode drift. Now, although many of the flints in the Northern drift, as Buckland contended, have most probably been transported from Lincolnshire or Yorkshire, the sudden increase in their number as the chalk escarpment of the Chilterns is approached clearly points to a derivation from that quarter. In other words, besides the Northern drift, there is in the neighbourhood of Oxford an Eastern drift; indeed, the general absence of local oolitic constituents would lead us to believe that this has been the principal source. Beyond the headwaters of the Thame the land is thickly covered by drift, and though little now remains in the lower reaches of the valley, this was one of the directions by which erratic materials were brought to the banks of the Thames. Another source from which they were probably derived is the basin of the Ouse, near Buckingham. This valley is cut through deep deposits of drift, which spread over the surrounding country to elevations as great as those near Oxford.[1] The drift extends to the watershed between the Ouse and Ray, and is cut off at the edge of the plateau N.E. of Bicester, where the ground falls towards a tributary of the latter river. It is there at a height of 365 feet above the sea. Clearly at one time it extended further into the Ray Valley, and probably was continuous with the outlier still existing on Bletchingdon Hill, near the Cherwell, though it has been almost entirely denuded from the intervening lowland.

To sum up, drift has entered this region along the courses of the principal rivers: Northern drift by the Windrush, Evenlode, Cherwell and Ray; Eastern drift by the Thame.

The origin of the drift has long been a matter of controversy. The want of stratification of the deposits, the erratic fragments and boulders, their dispersal independently of the minor physical features of the country, are characters which recall the boulder-clays of glaciated regions, and which are not explained by fluviatile, marine, or diluvial action. At the same time, though some of the stones have the appearance of ice-worn detritus, the absence of clear glacial striæ differentiates the drift of the Oxford region from normal boulder-clay. The difference is partly due to the nature of the constituents, the majority of which are pebbles from the New Red Conglomerate, well rounded before they became incorporated in the drift, and very unlikely to become striated. Further, the drift is nowhere thick, and is usually weathered from top to bottom. It is disturbed by the percolation of water and by slipping on the hillsides, so that any limestone blocks with glacial striæ would probably have been obliterated.

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[1] A. H. Green, Geology of the country round Banbury, &c., *Mem. Geol. Survey*; and H. B. Woodward, explanation of Horizontal Section, Sheet 140, *Geol. Survey*, 1891, p. 10.

A parallel case from another region may not be out of place here. In the Low Peak of Derbyshire there is drift consisting of pebbles from the New Red Sandstone, cherts from the Carboniferous and other stones embedded in clay, and commonly unstriated. The deposit, which is usually thin and deeply weathered, bears much resemblance to the drift of Oxfordshire. But in one of the deep pits on the limestone tract, where the stony clay is abnormally thick, blocks of limestone, beautifully polished and grooved by ice action, were obtained near the bottom. Here there is glacial drift from which all calcareous material in the upper part has disappeared, and which only at a depth of 15 feet shows the characteristic marks of glaciation. No depth so great has been observed in the Oxfordshire drift.

The glacial origin of the drift is supported by comparison with that of surrounding districts. Thus round Buckingham there are drifts consisting of bedded Oolitic gravel, blue stony clay, with blocks of well-striated Carboniferous Limestone, and clayey gravel of flint and quartzose pebbles.[1] The last type, which occurs on the Oxford and Kimeridge Clays, is the nearest analogue to the drifts of the Upper Thames, and since it probably at one time spread continuously down the Ray Valley, a close connection is suggested between the Oxfordshire drift and the undoubted glacial deposits of Buckingham. Further, as has been contended by Buckland and others who have followed him, the Evenlode and Cherwell Valleys link the Thames drift with that of the Vale of Moreton and the Midland Counties. We now know the latter to be chalky boulder-clay, a formation of undoubted glacial origin, covering a large part of Eastern England. The relations which the different drifts bear to one another have not been worked out in detail, but there is enough to indicate the former continuity of those in Oxfordshire with true glacial deposits.

Again, it was seen that the drift of the Evenlode occupies high ground above the level of an alluvial terrace, 90 feet above the river. This terrace, containing, as it does, quartzose pebbles derived from the drift, is a younger deposit, and the deepening of the valleys to their present levels has been effected at a still later time. The drift can be traced down the slopes almost to the level of the terrace, though actual contact is not anywhere seen. Hence the valleys must have been excavated to that level before some at least of the drift was formed. Now this is just the relation which the chalky boulder-clay holds to the old river gravels of the Lower Thames. They can be traced downwards to the level of a terrace about 100 feet above the present river, and have been proved to pass under it.[2] It is true that the terrace has not been followed continuously all the way from Oxfordshire to Essex, but it has been recognised at so many points at a corresponding elevation with respect to the river and to the more continuous lower terraces, that there is little doubt about the correlation. Thus there is reason to regard the age of the Evenlode drift as approximately the same as that of the chalky boulder-clay in the Lower Thames Valley.

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[1] A. H. Green, *op. cit.*

[2] T. I. Pocock in Summary of Progress for 1902, *Mem. Geol. Surv.*, App. viii. ; T. V. Holmes, *Quart. Journ. Geol. Soc.*, vol. xlviii., p. 365, l., p. 443, and *Essex Naturalist*, vol. vii., Nos. 1—3.

To sum up, the nature of the drift deposits, their geographical distribution, their relation to the glacial deposits of the surrounding regions, point with strong probability to the conclusion that this district has been overspread by ice in the early Pleistocene period.[1]

AGE OF THE DRIFT.

The question may now be considered whether all the drift described is of the same age. Leaving out of account the Wolvercot deposits, which, as we have seen, probably include no true glacial drift, the deposits of that character in this region are older than the high level river terrace at Hanborough, and were laid down when the bottoms of the valleys were 80 feet or more higher than their present levels. But it is possible that the gravels of Boars Hill, Cumnor, and Wytham, which are from 290 to 350 feet above the river, belong to an earlier stage in the denudation of the country. If these were diluvial or fluviatile gravels, the contention of Buckland, that they were formed before the excavation of the valley between the summits of Boars Hill and Shotover, would be unanswerable. The gravel at Chawley Hurst brick-pit does, indeed, show well-marked bedding, and no deposit of this kind could be formed in such a situation if the present waterways had been in existence. But the outliers of drift at the tops of these hills are at very varying levels, and for the most part consist of unstratified gravelly clay, which might have been formed when the adjacent valleys were filled with ice to a depth of 300 feet or more. They are situated opposite the debouchment of the Evenlode Valley, where on the glacial hypothesis four or five streams of ice met, bringing rock detritus from west, north and east. Most of the material would subside in irregular masses at different elevations as the ice melted away, while some would be sorted into layers by the water set free.[2] Thus there may have been a continuous mantle of drift from the tops of the Cumnor Hills to the low ground at Bagley Wood. Whether this was the case, or whether the drift belongs to two stages, separated by a period of erosion, is a question which requires for its decision a comparison with contemporaneous phenomena in other parts of the Thames Valley.

The drift at lower levels is sometimes rudely terraced, part being at about 130 feet above the rivers, and part about 200 feet. The drift-sheets at Freeland, west of Radley, and near Tiddington, are at the former level, those at the top of Bagley Wood and along the foot of the Chiltern escarpment (see Sheet 237) at the latter. But these must be distinguished from the later fluviatile terraces, for they have neither the ingredients nor the well-marked stratification of the river-gravels. Moreover, the drift not only covers the terraces, but is found on the slopes above them and between them, as though it had once been a continuous sheet. It is not uncommon to find terraces of this kind in regions formerly glaciated, and they appear to have been formed somewhat as follows: While the ice still covered the country, but was beginning to shrink into the valleys, sheets of water, more or less continuous, spread between its margin and the hill-slopes. While it was held in by the ice, the water effected little beyond cutting a ledge in the boulder-clay and planing off its surface, as appears generally to have happened in the case of the drift at 200 feet above the rivers, between the Chilterns and the Ironsand hills south of Oxford. But as the ice-barriers broke away, and the superficial drainage became more continuous, great erosive power would be exerted, and the drift would be scoured out and rearranged in rude layers at lower levels. The terrace at Freeland, which shows traces of bedding, is probably formed of drift redistributed at the final melting of the ice before the river systems resumed their normal course.

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[1] Phillips, while clearly recognizing the part played by ice, attributed the plateau drift to an epoch of glacial submergence. Geol. Oxford, pp. 462 *et seq.*

[2] Mr. Woodward is strongly of opinion that none of the plateau drifts can be regarded as the immediate product of land ice, in the sense of being boulder-clay: but that there are remnants of "washed drift" of glacial age.

In reference to the wider question of the correlation of the Oxfordshire drift with that of other regions, it must suffice to remark that the River gravels contain a mammalian fauna almost identical with that found beneath boulder-clay in the North of England. Hence the drift of Oxfordshire is probably older than the latest boulder-clay of the North. But what influence this later glaciation had upon the Thames Valley, and at what stage of its evolution, we are at present unable to determine.

ORIGIN OF THE RIVER-GRAVELS.

So long as the land remained covered by ice, the gravels were formed only of such material as had been transported in the ice. But as soon as the Lower Oolite formations became exposed to denudation, the rivers laid down stratified gravels composed of limestone pebbles, with only a subordinate amount of material derived from the drift.

At the present day, from the Cotteswold Hills to the North Sea, the alluvial deposits of the Thames are fine mud. In the Pleistocene period they were generally gravels of varying coarseness. This difference can only be accounted for by the greater velocity of the streams in the former period, and since the disposition of the gravel terraces along the valley slopes shows that the gradient was approximately the same as at present, it follows that the greater velocity was due to greater volume of water. How was this increased volume brought about? Two answers suggest themselves. First, the rainfall, instead of being distributed uniformly over the year, may have been concentrated in one season, so that the rivers were subject to periodical floods of great violence. Secondly, the same result may have been caused by the annual melting of snowfields near the sources of the rivers. After what has been said above, the second of these causes will be thought the more probable.

The formation of the river gravel was interrupted three times by episodes of erosion, during the first of which the river-bed was eroded some 50 feet. In this case the drop in the level of the high terrace between Yarnton and Radley may indicate a tilt in the bed of the river, which caused it to deepen its channel; but this is inadmissible as an explanation of the later stages of erosion, for the Oxford terrace is practically at the same level between Oxford and Yarnton. The cycles of erosion and deposition indicate changes in the volume of the rivers and the transported material. The complete dissolution under the influence of a warm climate, of snowfields in the Cotteswolds, would cause a reduction in the supply both of water and of rock detritus, and would leave the rivers free to erode their channels. A renewal of the snowfields would cause the erosion to cease, and the deposition of coarse sediments to begin again.

The later cycles of erosion are of much less significance, but they indicate similar changes in the state of the rivers. The shells in the lower terraces and some of the mammalia indicate an equable climate, but the mammoth and woolly rhinoceros betoken greater cold. Possibly each of these gravels was formed under the conditions of seasonal rainfall, or they may indicate a renewal of cold and snowfields on a small scale in the Cotteswolds, followed by a warmer climate, which allowed a temperate fauna to live in the valleys, while the shrinking snowfields in the uplands filled the rivers with coarse detritus of the rocks.

[NOTE—In connexion with the subjects discussed in this chapter the reader should consult the paper by Mr. F. W. Harmer on "Lake Oxford and the Goring Gap," published in abstract *Rep. Brit. Assoc.* for 1906 (1907), p, 572; and the fuller particulars given in his later paper. *See* Appendix.—H. B. W.]

CHAPTER XI.

DEVELOPMENT OF THE RIVER VALLEYS.

BY T. I. POCOCK.

The origin and development of the rivers of the basin of the Thames in its wider aspect is beyond the limits of this memoir, but the consideration of the problem in its relation to the formations and structure of the Oxford district may fittingly be given here. The rivers originated when the Midlands of England emerged from the Upper Cretaceous sea, unless it be supposed that the Eocene strata of the London basin extended over that region, in which case the beginnings of the present system must be in later Tertiary time. The movements which have determined the courses of the rivers have been the upheaval in the north-west, which gave the general south-easterly dip to the strata, and undulations of much lesser magnitude inclined obliquely to the main line of movement; and since the Eocene strata on the slopes of the Chilterns have been involved in the movements, it is not unreasonable to connect them with the post-Oligocene disturbances of the south coast.

In the first instance, when the land emerged from the waters of the sea, the rivers would rise in the highest ground and flow down the slopes approximately in the direction of the dip of the strata, following any depressions in the surface that came in their way. Such rivers, which are called "consequent," are represented in our region by the Cherwell, the Glyme, the Evenlode, and less obviously the Windrush.[1] When in the progress of erosion the soft beds of clay became uncovered, the tributaries would cut rapidly back along them, and divert the smaller consequent rivers into those which had cut deeper channels. In course of time, a system of "subsequent" rivers will thus be developed, flowing along the strike of the softer strata, independently of the original tilt of the surface. In our region the Upper Thames forms a perfect example of a subsequent river, following the broad belt of Oxford Clay almost from its source to Yarnton, where it turns southward into the older Cherwell Valley; and in all probability it has been developed by the tributaries of the Evenlode and Cherwell, pushing back their head waters and capturing the consequents which flowed down the slopes of the Lower Oolitic upland. The Ray, the Thame, and the Ock, are less perfect examples, whose courses have been more or less modified by the structure of the formations through which they flow.

Taking the consequent rivers first, it will be seen by examining a small scale map (such as the index map of four miles to an inch) that the Evenlode and Cherwell do not flow exactly at right angles to the strike of the Oolites, but in somewhat oblique directions. In reality, they follow slight downfolds or dislocations of the strata, which are apparent if the geological boundaries are traced in reference to the contour lines. At the Sandford gap the Corallian rocks bend upward at low angles on both sides of the river, though the prevalent dip of the region is almost in the direction of flow. Again, higher up the valley, the outlier of Oxford Clay at Tackley indicates a downfold in the Jurassic strata.

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[1] See also W. M. Davis, *Geograph. Journ.*, v., 1895, p. 145; and H. J. Osborne White, *Proc. Geol. Assoc.*, xv., 1897, p. 170.

In the case of the Evenlode the Great Oolite strata incline slightly upwards from the river on the Combe side and on the Long Hanborough side, while further west there is a small fault in the direction of the valley near Stonesfield. The Windrush, again, passes from the Oolite country near Witney on to the Oxford Clay close to a fault. But whether the upper reaches of the valley and those of the Glyme, which lie outside our region, are likewise determined by rock-structures has not yet been ascertained.

Thus the two principal consequent rivers of the district have eroded their channels along downfolds of the strata, which not improbably correspond with the original depressions in the Chalk platform on which they took their rise. The much more powerful dislocations which elevated the Lower Oolites along the present Ray Valley, and the faults between Islip and Wheatley, have had little influence on the course of the rivers, probably because they are of older date and were entirely concealed by Upper Cretaceous strata at the time when the present arteries of drainage originated.

The early development of the river valley is largely matter of conjecture, though the broad lines upon which it has been worked out can be understood. Before the Gault and Iron-sand of the hill-tops round Oxford were uncovered by erosion, some 800 feet of Upper Cretaceous strata had been removed. There was then probably a plain of Gault clay over the site of the city, with a steep range of Chalk hills, a few miles to the south, through which the united waters of the Cherwell and the Evenlode flowed in a narrow gap such as now exists at Goring. It is possible that the Windrush had an independent course further west in a direct line with the gap in the Berkshire Downs, through which the railway runs from Didcot to Newbury, and there may have been one or more consequent rivers to the east which were afterwards diverted by the Ray and the Thame; but as yet we have no indication to what extent the Upper Thames and other subsequent rivers had been developed.

At what geological period the denudation of the land reached this stage it is very difficult to decide. According to Prestwich,[1] since the beginning of the Pleistocene period, when the so-called "Westleton beds" were formed, there has been erosion of the valleys to a depth of 450 feet, the greater part of which was accomplished during glacial times. If this be thought excessive and inconsistent with what is known of the Ice Age in other regions, it must be said that as yet we know little of the events which preceded the formation of the chalky boulder-clay, and of the extent to which such soft strata as the Oolitic and Lower Cretaceous formations may have been worn down by ice-sheets and by the flood waters liberated at their melting. An epoch of erosion may have intervened between the formation of the pebbly clay at the top of Boars Hill and that at lower levels nearer the rivers. On the other hand, it is possible that all the drift may have been deposited after the valleys had been cut down to a depth 80 feet above the present water-courses, and when they were filled by several hundred feet of ice. Be this as it may, the landscape of the whole region is essentially one of river formation, and the characters impressed upon it during the Ice Age have been practically obliterated by the prolonged denudation of later times.

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[1] *Quart. Journ. Geol. Soc.*, **xlvi., 1890, pp. 84–181.**

Our knowledge of the system of rivers and brooks which carved out the highest summits of our region—Brill, Shotover and Cumnor Hills—is very imperfect, but the survival of these isolated beds of sand is due primarily to their position between the water-courses. There is, however, another cause. Within the limits of our region the Gault clay overlaps in succession all the underlying strata down to the Kimeridge Clay, so that a large part of the Portland Beds and Ironsands must have been swept away by an earlier denudation preceding the Upper Cretaceous period. The long stretch of relatively low ground between Cumnor and Faringdon is in all probability due to the absence of any resistent strata between the Kimeridge and Gault Clays which once covered the Corallian plateau. This is quite in accordance with the fact that in the vale of the White Horse the two clays are in contact all the way from Culham to Uffington. The wide gap between Shotover and Brill may also in part be ascribed to the same cause.

The sculpture of the features of lower elevation is closely connected with the growth of the subsequent rivers. There are three belts of soft strata on which these might have been developed: the Oxford, Kimeridge, and Gault Clays. But in reality the last two are so frequently in contact that they have not given rise to independent river-systems. The escarpment of Corallian rocks which crosses the region from south-west to north-east has been made by the erosion of the Upper Thames and the Ray along the broad belt of Oxford Clay. The Thame and its tributaries cut out the network of valleys among the sandy hills on the eastern border of the county. Yet though the Thame runs approximately in the direction of the strike of the Kimeridge Clay, it was probably in the first instance a subsequent river on an outcrop of Gault, and the later deepening of the valley since the glacial period has been guided by undulations in the Lower Greensand and Portland strata. Between Thame and Wheatley the direction of the river is nearly east and west along the axis of a downfold, for the strata dip at low angles towards the river-bed on both sides. The sharp bend to the south near Wheatley is occasioned by the uplift of the strata on the west side towards Shotover Hill.

When the rivers resumed their normal courses after the disappearance of the ice, and began to lay down the gravels of the high terrace, we find the present system fully developed, but without many of the complications which supervened in the later stages.

The Upper Thames followed a direct course along the Oxford Clay from Fairford to the north of Yarnton, several miles distant from the present channel. The Corallian escarpment on the right bank stood at a much greater height and in a position more to the north-west than now, the curve at Appleton not being then in existence. On the left bank the Oxford Clay rose in gentle slopes to the drift-clad hills of North Leigh and Bladon Heath, between which the Evenlode emerged from its upland gorge and formed the delta of gravel at Hanborough. Farther east the Thames was joined by the Cherwell near the outlier of gravel above Yarnton, and the united rivers flowed over the site of Oxford, crossing the strike of the strata in the same direction as at present, but in a more direct line, as the curves of Nuneham Park and round the hill at Culham had not yet been formed. Besides these rivers, the Ray was a tributary from the north-east, entering the main valley over the shoulder of Noke Hill, but since it flowed through a clay country and was not fed by any important tributaries from the Oolite uplands, no gravels remain to mark its former channel. There was a river of considerable magnitude, perhaps the Windrush itself, running through the Wilcote Valley into the Evenlode. But this was probably diverted, and entering the main valley by Witney, laid down its gravels on the margin of the Thames.

The vale of the White Horse was traversed by the Ock, but the river-bed lay further to the north than at present, and its old alluvia have for the most part been swept away.

Lower down the valley of the Thames the main river was joined by the Thame, probably not far south of Stadhampton, though here also the high terrace has almost entirely disappeared.

The enormous denudation which has taken place since the epoch of the high terrace is strikingly illustrated by the position of the outlying remnants. The water which laid down the gravels would under present physical conditions overflow into the basins of the Ouse in the north-east and the Avon in the south-west, besides crossing the Corallian escarpment near Fyfield and drowning many low-lying valleys in the district. It is clear that at all these points the land must at the time have been at a much higher level. The denudation which has since taken place is illustrated by the accompanying diagram. As soon as the gravel ceased to be formed and the rivers began to cut down their channels, the great delta of the Windrush south of Witney compelled

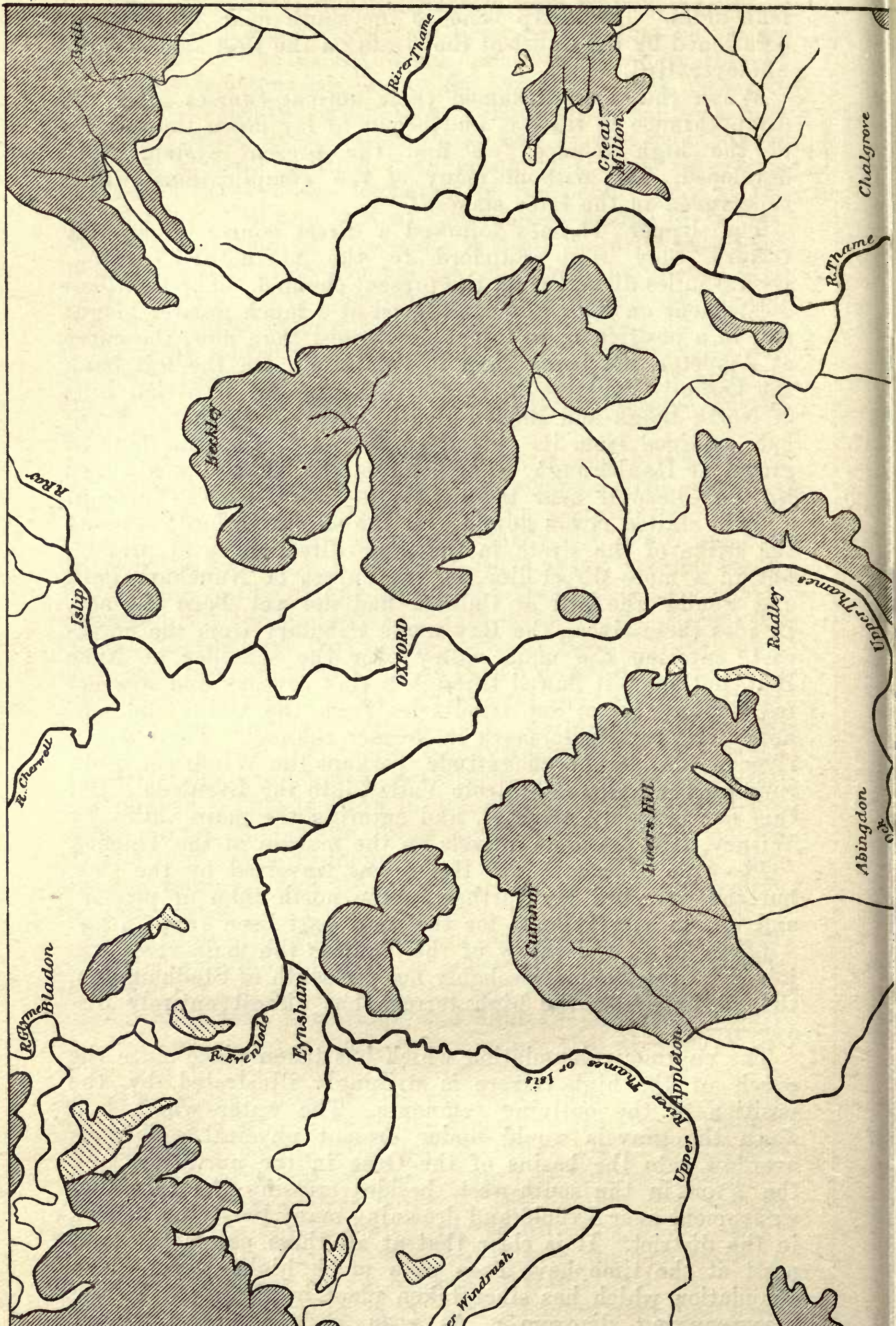

FIG. 11.—*Map showing Denudation of Valleys since the formation of the High Terrace.*

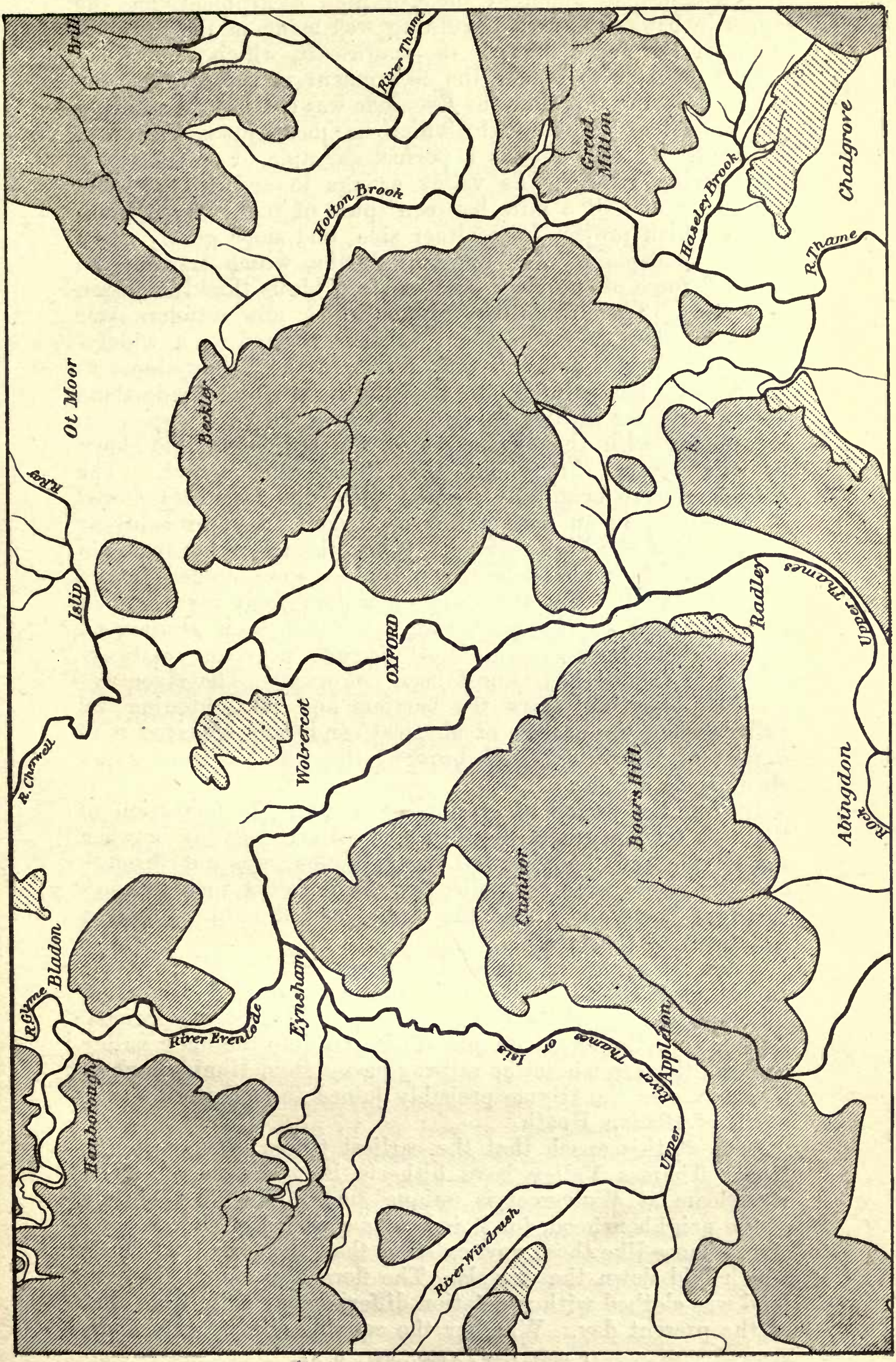

FIG. 12.—Map showing Denudation of Valleys since the epoch of the Wolvercot Terrace.

the Thames to undercut the Corallian escarpment on the opposite bank. Thus a beginning was made in the development of the curve towards the south-east, which is destined sooner or later to reduce the escarpment to the level of the plain. During this time the Evenlode was cutting the winding gorge west of Hanborough, which has been justly described by Prof. W. M. Davis as a perfect example of erosion by a meandering river.[1] The valley swings to and fro with an amplitude of half a mile between spurs of turf-covered limestone, which project from either side and slope gently down to the flood-plain. The opposing banks, which encountered the full force of the river, rise in steep bluffs thickly covered by woods. The diminutive stream which now wanders over the flood-plain is incompetent to have formed such widely-sweeping curves, and the very forms of the valley show, as Prof. Davis has pointed out, that the river which made them flowed with far greater volume. This, as we have seen, is in accordance with the characters of the sediments laid down by the rivers throughout the Pleistocene period. The meanders were originally formed when the Evenlode flowed at base-level in an open valley of Oxford Clay, probably at the epoch of the high terrace. When the rivers began again to deepen their channels the meanders were eroded into a winding valley. But the work of erosion went further than this, for each of the projecting spurs has been scarped on the side facing upstream, and the one near the railway-bridge at Combe has almost been cut away. The river was steadily breaking down the barriers and straightening its valley when the change of physical conditions deprived it of a part of its waters, and brought the work of destruction abruptly to a close.

During the period of erosion succeeding the formation of the high terrace gravel the thin layer of Oxford Clay between the Glyme and the Cherwell, near Bladon, was cut through and the rivers were compelled by the resistent rock to work eastward along the dip of the strata, and thus to lay bare a wide area of Cornbrash.

After the agents of erosion had deepened the valleys to the extent of from 40 to 60 feet, another epoch of deposition followed, during which the terrace of Wolvercot was formed. At this time the Evenlode flowed directly into the main valley through the gap where the railway passes from Hanborough to Yarnton, and the Glyme probably joined the Cherwell to the north of Bladon Heath.

It is at this epoch that the earliest traces of man in the Upper Thames Valley have hitherto been discovered. The river-loam at Wolvercot is unique among the older alluvia of the neighbourhood, for it indicates a period of slow-flowing rivers, more like those now existing than the torrential floods which laid down the gravels. The flora also shows that the land was clothed with vegetation differing but little from that of the present day. Whether the equable climate thus indicated was followed by one of greater severity, in which glacial conditions again held sway in the Thames Valley, cannot as yet be clearly proved, but the torrential floods which formed the earlier gravels returned in full force at the epochs of the lower terraces. After the formation of the Wolvercot terrace the rivers eroded their channels to a depth of about 20 feet before the gravel-terrace of Oxford was formed. It was about this period probably that the Evenlode and Glyme assumed their present courses. In eroding its channel in the limestone near Hanborough, the Evenlode was led by the easterly dip of the strata into close proximity with the Glyme. Eventually, between the epochs of the Wolvercot and Oxford terraces, the barrier was broken, and the Glyme, quitting its old channel, henceforward became tributary to the Evenlode. At about the same time the Evenlode itself changed its direct course into the Thames Valley, for one which is almost contrary to the flow of the main river. A change in the dip of the strata appears to have been the cause, as in the previous case. Just south of the railway-bridge, where the alluvium of the Evenlode expands to a breadth of three-quarters of a mile, the Oolites on the right bank roll over slightly and dip towards the south. As soon as the river in the process of eroding its channel struck the Cornbrash rock, it began to cut a notch in the bank in the direction of the dip. Gradually, with the help of the springs thrown out from the neighbouring high terrace gravel, a new channel was cut, and the Evenlode found its way to the Thames between Cassington and Eynsham.

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[1] *Proc. Geol. Assoc.*, xvi., p. 87.

Meanwhile a marked curve had been developed in the main valley opposite the mouth of the Windrush, and at Abingdon the Thames had worked its way westward, avoiding the resistant Ironsands, and passing to the Gault plain at a point where it is in contact with the Kimeridge Clay.

By the time this phase of erosion ceased and the rivers spread out the gravels of the second terrace, most of the adjustments in their courses had been completed, and their gradients were nearly the same as at present. From the old mouth of the Windrush to the point where the Thames turned southward there is a fall of about 30 feet, but the constriction of the valley by the Corallian escarpment ponded back the flood-waters, and caused them to drop their sediments on an almost level plain as far up as the confluence of the Cherwell with the main river. Below the Corallian gap there is a drop of 20 feet to the plain of the second terrace between Radley and Abingdon. After the formation of this gravel there was another phase of erosion, in which the river valleys were cut down to about their present depth, some 20 feet below the second terrace, and a further development of the features already described took place. In the west the delta of the Windrush again compelled the Thames to cut back the Corallian escarpment on its right bank, and the slope of Ironsand on the left bank opposite Radley was pushed farther to the southward, but in the intermediate part of its valley between Yarnton and Iffley the river eroded its channel through the middle of the second terrace, leaving remnants on either side. It was at this time that the Cherwell deserted its direct channel into the Thames and turned eastward to join the Ray near Islip. The cause of the diversion is similar to those already described. Near Kidlington the Great Oolite formation rises in a low ridge across the valley perhaps along a line connected with the upheaval at Islip. When erosion was renewed after the epoch of the second terrace the river avoided the barrier by cutting eastward along the Oxford Clay into the Ray Valley.

The gravel which was formed after the valleys had been cut down to their present levels, is less extensive than that of the second terrace. It descends in level some 25 feet in the upper valley, but between Yarnton and Iffley there is scarcely any change. South of the Corallian gap there is a drop of 20 feet, as in the case of the second terrace. There has been little change in the river valley since this gravel was deposited. In a few places it has been cut through, and near Appleton the Corallian escarpment has been undercut a little farther, and the Thames has changed its course at Shifford. On the other hand, the interval of time between the gravel and the recent alluvium was probably a long one, for it witnessed the extinction of all the large mammalia as well as of palæolithic man. It would seem that the rivers had cut down their channels to a base-level during the Pleistocene period, and could make no further progress until an upheaval caused a fresh cycle of erosion to begin. No such upheaval seems to have occurred. It has however been shown by Mr. F. C. J. Spurrell that in the Thames below London there has been erosion of at least 70 feet since the lowest terrace was formed, and that the channel has been filled by peat and marine alluvium during subsequent inroads of the sea. The same is true of other English rivers. Thus there are records of river development beyond our coasts, buried under the seas, of which there are no traces in the upper reaches of the valleys. After the lowest gravel terrace had been laid down, the physical conditions of the Pleistocene period passed away, the rivers no longer flowed in torrential floods, and the later deposits laid down in the region of the Upper Thames consist of fine loams and clays of the recent flood-plain.[1]

The plain of Ot Moor, which is the most conspicuous tract of alluvium in the region, appears to have been formed by river erosion partly before the drift period and partly after. Ultimately the cause of this wide alluvial flat was the uplift of the Lower Oolites on its western and northern sides, and its growth may have been as follows.

While the Oolite inliers were covered by Oxford Clay the Ray flowed in a longitudinal valley, passing somewhere between Islip and the top of Noke Hill. When in the process of cutting its bed the river struck the Oolite formation under the clay, it sought a channel by the nearest hollow in the rock surface, which happens to be exactly where it now escapes into the main valley. There are traces of terracing on the side of Noke Hill which appear to be independent of the structure of the strata, and may be rock-ledges cut by the river at the epochs of the Hanborough and Wolvercot gravels.

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[1] See also Prestwich, *Quart. Journ. Geol. Soc.*, xlvi., p. 151.

Meanwhile the lateral erosion of the Oxford Clay proceeded much faster than the cutting of the channel, and a broad river-plain was formed, parted by a rock barrier from the Thames Valley, except where the river had formed its narrow opening.

The sudden disappearance of the Corallian Limestone made the erosion south-east of Ot Moor more easy than it would have been with a thick protecting mass of rock.

Besides the channel in the Great Oolite at Islip, Ot Moor is connected with the Cherwell by two others in the Oxford Clay, and with the Thame by a third, also in Oxford Clay. These belong to a class of valleys not unusual in the Oxford region, which contain no streams flowing from end to end, but cross the watersheds from one system of drainage to another. They are most probably due to abnormal conditions in the strata. Those round Ot Moor must have been developed subsequently to the gorge at Islip, else the Ray would have escaped by an easier channel into the Cherwell or Thame.

The valleys both by Wood Eaton and to the north of Islip are in positions where there is much faulting, and they may coincide with lines of fault. In either case the outflow of springs where the Oolite was in contact with the clay would cause abnormal erosion at those points, and the tributaries of the Cherwell on the one side and of the Ray on the other would soon cut back to the water-parting. A somewhat different explanation must be given of the longer cross-valley connecting Ot Moor with the Thame, for here there is no sign of faulting. And yet there is nothing that would indicate that the lacustrine plain was ever drained by a river to the east. But we know that along this line the Corallian Limestone disappears abruptly and is replaced by clay. Where the permeable rock passed into the impermeable clay the water would be thrown out in springs flowing in opposite directions to Ot Moor and the Thame, and erosion would be especially active. It is the cutting back of such opposing streams into their watersheds which has probably made this remarkable cross-valley along the line of transition between the Coral Rag and the Ampthill Clay.

The best known instance of a cross-valley in the neighbourhood of Oxford is the one followed by the Eynsham road between the hills of Wytham and Cumnor. This valley at its highest point is only 30 feet above the level of the Thames west of Oxford, and has been supposed to be an old course of the river. But of this there appears to be no evidence, for although the river gravels run up the valley for some distance at either end, they are not continuous through its whole length, and prove no more than that in the later stages of erosion the flood waters carried their débris into bays cut in the hill side. It is more probable that the origin of the valley is connected with the disturbance of the strata which has been shown to occur there. The effect of a fault in bringing Corallian strata in juxtaposition with Oxford Clay, would be the outflow of copious springs into the Thames in opposite directions along the plane of contact, resulting ultimately in the degradation of their channels below the level of the water-bearing strata. The same thing would happen if, instead of a fault, there is a synclinal fold, for the water would collect and flow out at the lowest level of the permeable beds. (See Fig. 6, p. 32.)

One other instance of a cross-valley may be noticed. This passes from the Thames Valley, between the Portlandian hills at Garsington and Toot Baldon, into the Thame Valley, and is probably connected with the overlap of the Gault on the Kimeridge Clay on the eastern side near Chislehampton. Where the two clays are in contact the rate of denudation must necessarily have been greater than where resistent Portland and Ironsand strata were intercalated. For this reason probably the feeders of the Thame were able to cut back into the watershed faster than those of the Thames, and to capture some of their head waters. Hence the Baldon Brook, rising on the west side of the hills, instead of falling into the Thames, passes over an alluvial flat 40 feet above the present rivers, and escapes by a circuitous course through hilly ground into the Thame below Chislehampton.

The brooks which feed the main rivers are chiefly derived from three sources:—

1. The Portland Beds and Ironsand of the higher hills.
2. The Corallian formation.
3. The Pleistocene gravels.

Most of these brooks are of small size, and have originated late in the history of the land-surface, yet some of them have cut deep valleys, and have had important influence in imparting to the landscape its present form. The great clay formations have few permanent springs, for most of the water which falls on the surface is carried away, on account of the absence of porous beds through which it can pass underground. The gravels, sands, and limestones, on the other hand, readily absorb rain water, and throw it out in innumerable springs where the impervious clays crop out from beneath them.

Besides the sources mentioned, there are others in the north-west and in the south of equal importance, but only a few brooks derived from them come within the limits of the map. The brooks in the Wilcote Valley rise in the limestones of Wychwood Forest. The chief branches of the Great Haseley and the Chalgrove brooks, tributaries of the Thame, flow from the Chalk rocks of the Chiltern Hills. Many of the feeders of the Ock are derived from the same formation in the

Berkshire Downs. These belong to distinct hydrographical systems which lie almost entirely outside our limits.

The first of the three sources mentioned above is that which gives rise to most of the longer brooks, since they traverse a considerable extent of Corallian and Oxford Clay lands before they reach one of the trunk streams. A number of tributaries of the Thame have their head waters in the sands of the Brill range of hills. Danes or Holton Brook, and the brooks at Oakley and a mile to the west, are the longer. The first rises in a combe on Muswell Hill, and flows in a valley 70 feet deep along a slight downfold in the Calcareous Grit plateau of Studley as far as Menmarsh Farm, where it is joined on a broad alluvial flat by affluents from the Corallian on both sides. Thence it continues as the Holton Brook along the line of transition between the Coral Rag and the Ampthill Clay, and joins the Thame between Wheatley and Waterperry. The other two brooks rise in the sands of Brill and flow approximately in the direction of the outcrop of Ampthill Clay. They are probably guided by the strike of hard bands in the clay, which have been eroded into slight escarpments.

Further south the Portland Beds and Ironsands are close to the river between Cuddesdon and Great Milton, and the brooks flowing from them are correspondingly short. But the Baldon Brook is longer, for part of its waters head from the sands of Garsington and Toot Baldon on the hillsides facing the Thames, and flow through a gap to the Thame below Chislehampton. The sands of the Shotover range give rise to several large tributaries of the Thames and Cherwell. The Bayswater Brook on the north rises in Forest Hill, and flows through a gorge in the Corallian rocks, from which it gathers many affluents, into the marshland east of Marston, finally escaping by an open valley into the Cherwell, south of the village. The position of the gorge, as in so many other instances, seems to be determined by a slight downfold of the Corallian rocks.

The Northfield or Hollow Brook, rising east of Horsepath, is, perhaps, guided near its source by a downfold of Portland Beds, but lower down, near its confluence with the Isis, it runs almost parallel with the main outcrop of the Coral Rag, and its path has been determined by the strike of the harder and softer beds. The Ironsands of Boars Hill and Cumnor are nearer to the Isis than those of Shotover, so that the brooks have a steeper descent to the trunk stream. Accordingly we find that, though the brooks are small, they have cut a series of straight gorges in the Corallian plateau, which for narrowness and steep declivities might be called cañons. These are the well-known valleys near North and South Hinksey.

On the west side of Boars Hill the brooks are tributaries to the Ock, which flows approximately along the boundary of the Corallian and Kimeridge Clay. There is no limestone plateau to be cut through before they reach the main stream, as on the Oxford side. Hence their valleys are wide and shallow, following the same beds of rock for considerable distances upon the dip-slope. The largest tributary is the Sandford Brook, which gathers its affluents from the northern part of the hill, flows along the boundary of the Coral Rag and Calcareous Grit below Dry Sandford, and reaches the flood-plain of the Ock near Marcham.

The springs derived from the Corallian formation are less important individually than those of the Portland-Ironsand group, but they are more numerous, and a greater population is dependent on them. They are thrown out either by the Oxford Clay at the base, or at points where the plain of saturation reaches the surface, or by impermeable beds within the formation itself. The former need not be mentioned individually. They rise in little combes all along the base of the formation, and descend the slopes of Oxford Clay directly to the Thames, the Cherwell or Ray; or else are affluents of some larger stream of the Portland-Ironsand group. They are indicated on the map by the indentations in the boundary of the Oxford Clay and Calcareous Grit, each of which marks a spring.

The other Corallian streams occur for the most part on the dip-slope west of Boars Hill, over which in some cases they flow for several miles before they reach the Ock in the vale of the White Horse. One of these may be specially mentioned, as it illustrates the geological structure. Rising near Cumnor, probably in a bed of clay, it flows by Appleton to Fyfield, guided by the outcrop of hard beds of grit. Here the axis of a downfold is reached, and the spring turns across the strike of the strata till it reaches the Coral Rag, and then once more follows the outcrop till it reaches the plain of the Ock at Marcham. The tributary has been developed partly as a transverse and partly as a longitudinal stream.

The springs derived from the Pleistocene gravels are probably as numerous as those from the Corallian formation. They flow out from gravels of different ages, from the second terrace to the drift, for each deposit as soon as it was cut through by the river gave rise to a fresh set of brooks, which have ever since been at work cutting back the gravel from which they originated. The destruction wrought by the older Pleistocene brooks upon the high terrace and the drift, has been so great that these gravels have been reduced to outliers of insignificant size and deeply trenched by combes. Many of these brooks must have dried up, owing to the complete denudation of the gathering ground, while others have cut into the underlying formations and opened fresh sources of water. The enormous extent to which this process has been carried has been pointed out in the account of the drift. In the Thame basin so much of the drift and high terrace gravel has been removed that the natural drainage has been practically remodelled, since the land has, in many parts, been eroded to the base of the Portland Beds, from which a newer set of brooks have taken rise. Only a few small tributaries now have their sources in the drift plateau by the Thame.[1]

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[1] See also A.-M. Davies, *Proc. Geol. Assoc.*, xvi., 1899, p. 56.

The denudation has not been so great in the region of the Upper Thames. At one time the whole surface between Witney, North Leigh, and Eynsham was covered by the Northern drift. The brooks at first were short tributaries, flowing from the base of the gravels down the clay-banks into the Thames and Windrush. Gradually they cut backwards and developed secondary tributaries, till the Pleistocene deposits were divided into outliers near the local watersheds. Meanwhile the channels were deepened till the Kellaways Sands, near the base of the Oxford Clay, were reached, and new supplies of water came to reinforce the waning springs from the gravel. The brook between Church Hanborough and Freeland has cut back almost to the Evenlode between the high terrace and the Northern drift, and has laid bare the Cornbrash in part of its course, but its principal feeders still flow from the drift. The Chil and the Limb Brooks, west of Eynsham, are now fed principally from the Kellaways Sands, the gravels being for the most part denuded, though some of the affluents still rise in the drift of Eynsham Park. Near South Leigh there is an interlacing system of marshy hollows, formed by affluents which have cut back into the water partings.

The brooks between New Yatt and Witney have gone further in the work of erosion. Not only has the drift which gave them birth been swept away between New Yatt and North Leigh, but both the Kellaways Beds and the Cornbrash have been cut through, and two fresh sources of water uncovered.

CHAPTER XII.

ECONOMIC GEOLOGY.

BY H. B. WOODWARD AND T. I. POCOCK.

WATER SUPPLY.

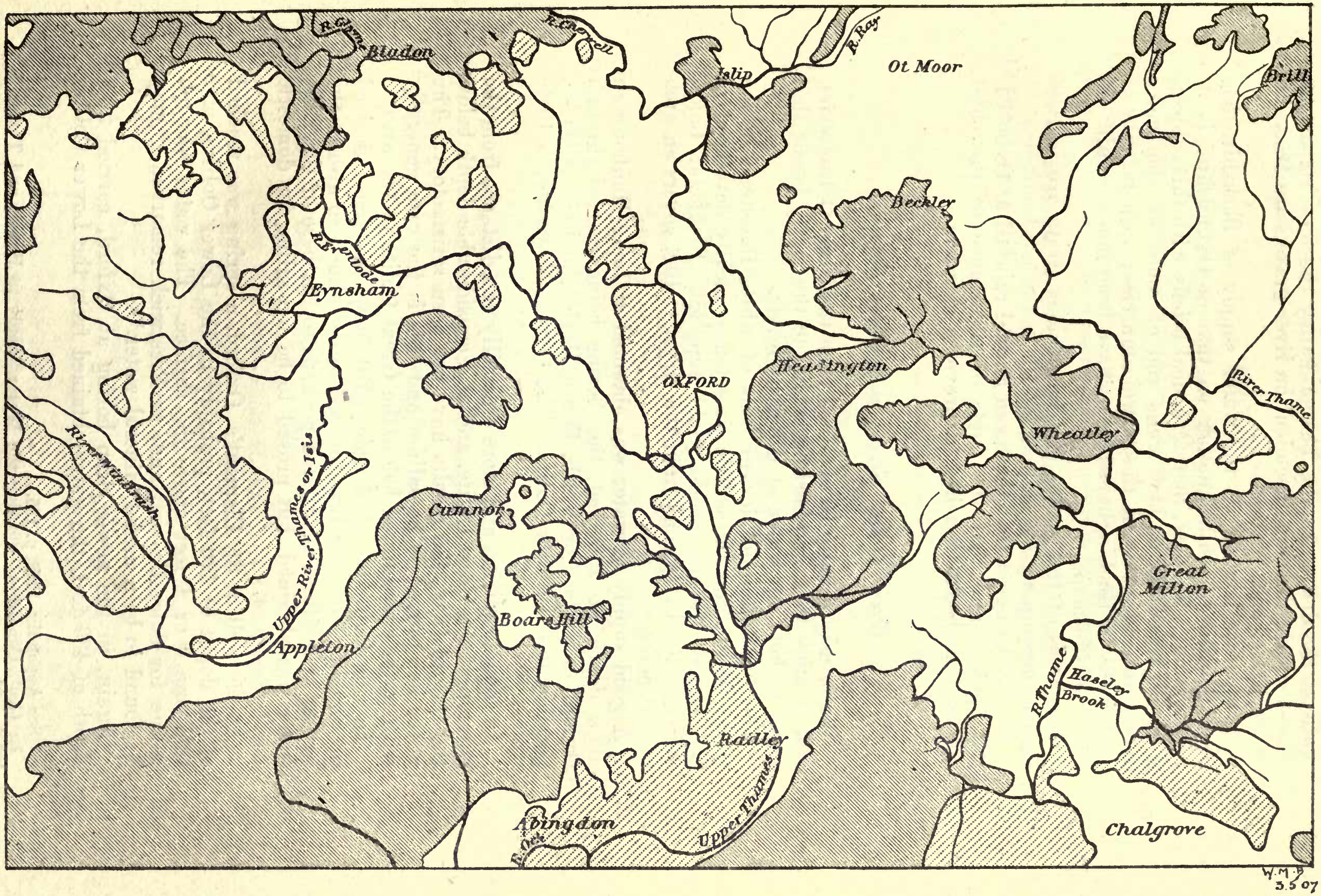
The sites of towns and villages throughout the district depend primarily on the occurrence of water-bearing strata. (See Fig. 13.) They fall naturally into groups corresponding to the main sources of the springs, namely, those on the Lower Oolites, those on the Corallian outcrop, those on the Portland and Ironsand Beds, and those on the superficial gravels. The first group, of which there are very few within the map, includes Oddington, Islip, and Bladon. The second group is represented by the line of villages extending from Hinton Waldrist to Cumnor, and from Sandford to Headington and Beckley, and round the outcrop to Wheatley.

Eastward, on the lands where the Corallian limestone is replaced by the almost waterless Ampthill clay, a very marked decrease takes place in the population. Only two small villages—Studley and Boarstall—are built upon the diminutive representative of the Calcareous Grit N.E. of Beckley. Oakley, Worminghall, and Ickford, though situated on clay land and drawing their well-water from permeable bands in the clay itself, are in the vicinity of large streams flowing from the Portland Beds of Brill. The population in this quarter is concentrated at higher levels, such as Brill and Long Crendon, where the Portland and Ironsand Beds yield an abundant supply of water, which is wanting on the low clay-lands. Indeed, there is no instance in the whole district of a village situated on the great clay formations except it be close to the boundary of a water-bearing formation, or to a brook flowing from them. In the S.E. of the district where the Portland and Ironsand Beds spread over a wide area the greater number of villages are dependent on them; those encircling Shotover Hill, Horsepath, Garsington, Denton and Cuddesdon, and the new suburb of Oxford on Boars Hill, also belong to the same group.

The areas of gravel contain by far the largest population, each bed from the lowest river terrace to the plateau drift having been made use of as sites for villages.

Brighthampton, Standlake, Northmoor, Kidlington and the Hinkseys are on the lowest gravel; Oxford and Abingdon and almost all the villages in the Thames Valley are on the second; Upper Wolvercot and part of Radley on the third; Hanborough on the fourth; Freeland, North Leigh and New

FIG. 13.—*Map of the Water-bearing Strata of the Country around Oxford.* (T. I. Pocock.)



Water-bearing strata *shaded*; and, for superficial gravels, *stippled*. Impermeable, and practically impermeable, superficial areas, *blank*.

Yatt on the drift. In the Thame Valley the most important places within the map dependent on river-gravels are Drayton, Waterperry, and Waterstock.

A separate memoir on the water supply of Berkshire has been published,[1] while another on that of Oxfordshire is in preparation. We may, therefore, deal briefly with this subject, giving particulars of new wells and of some of the more important old wells in those two countries; also records of such wells in Buckinghamshire as have been made within the limits of the map.

The areas of the porous and impervious strata are marked on the accompanying map, Fig. 13.

It may be noted that the mean annual rainfall at Oxford is 25½ inches, and that the mode of occurrence of the chief springs has been described in previous chapters.

Great Oolite Series and Older Strata.

Water may usually be obtained from the Great Oolite series, and at more than one horizon, owing to the marly bands that serve to hold up water at different levels.

The freestone and thicker beds of white limestone in the Great Oolite, and the oolitic limestones, locally developed in the Forest Marble, would yield supplies. Blenheim Lake, which is fed by springs from the Great Oolite, covers an area of 250 acres.

A good supply of water was obtained at Long Hanborough at a depth of 138 feet, the boring being carried through Oxfordian strata, Cornbrash, Forest Marble, and Great Oolite, possibly into Inferior Oolite. The Cornbrash yielded a little water.

In some localities, and more especially at a distance from the outcrop of the Great Oolite, and at a considerable depth below the Oxford Clay, the results have not been satisfactory. The water has proved to be saline, and this is the case generally with water encountered below the Great Oolite in the area.

In the deep well at Witney (270 feet), the water derived presumably from the Lias proved to be saline; so also in the boring at Kidlington, carried perhaps to the base of the Lias, water was obtained, but proved to be too saline for domestic use. (See p. 4.)

At the well at St. Clement's, Oxford, a spring was reached at the depth of 420 feet, probably in the Lower Oolites, and this rose 3 or 4 feet above the surface. The water was too saline for domestic use, and, as Prestwich remarked, "may be found to be a useful mineral water."[2]

Again, in the newer deep boring at Oxford, carried to a depth of 439 feet, the water obtained from the Lower Oolites was highly saline. The following is a record of the strata passed through:—

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[1] See Appendix, 1902, p. 135.

[2] "Geol. Conditions affecting the Water Supply to Houses and Towns," 1876, p. 31.

OXFORD.

City Brewery. Messrs. Handley & Co., 1898.

Boring made and communicated by Messrs. LE GRAND and SUTCLIFF.

Description in square brackets by J. H. Blake, from examination of the cores at the time of the boring, with additions by H. B. Woodward from specimens brought to the Museum at Jermyn Street by Messrs. Le Grand and Sutcliff.

Surface of the ground about 209 feet above Ordnance Datum.

Water obtained from depth of about 400 feet overflowed, but proved to be highly saline.

		Thickness.		Depth.	
		Ft.	in.	Ft.	in.
[Valley Gravel, &c., 30 feet]	Top soil [made ground, gravel, &c.]	7	6	7	6
	Sand and gravel [derived mostly from Oolites]	5	6	13	0
	Gravel, coarse at 21 feet [derived mostly from Oolites]	11	6	2	6
	Yellow clay and stones [gravel and clay]	5	6	30	0
[Oxford Clay, 210 feet]	Blue clay	125	6	155	6
	Clay and shells, *Pteria*	1	6	157	0
	Blue clay, *Pecten*	3	0	160	0
	Blue clay and shells	18	0	178	0
	Blue clay	31	0	209	0
	Blue clay and shells	7	0	216	0
	Shelly rock...	1	6	217	6
	Sandy clay, shells and mundic (pyrites), also lignite	5	0	222	6
	Shelly rock	2	0	224	6
	Hard clay and shells	7	0	231	6
	Hard clay, shells and mundic ...	6	6	238	0
	Sandy clay	1	0	239	0
	Ditto *Gryphœa dilatata* and iron pyrites	1	0	240	0
[Cornbrash, 17 feet]	Hard shelly rock [dark bluish-grey limestone at 241 feet]	17	0	257	0
[Forest Marble, 32⅔ feet]	Hard clay and shells	12	0	269	0
	Hard shelly rock [thin bands of dark grey oolitic shelly stone, with white grains, Echinoderm spine (*Acrosalenia* ?) and sandy clay at 272 feet]	19	0	288	0
	Hard rock and bands of clay [sandy]	1	8	289	8
[Great Oolite, 88 feet]	Hard shelly rock [grey and whitish oolitic stone at 300 feet]	29	0	318	8
	Bands of rock and clay with shells [sandy limestone at 327 and 332 feet, micaceous, whitish and greenish-grey]	39	4	358	0
	Rock	6	0	364	0
	Bands of rock and clay	1	6	365	6
	Rock	1	7	367	1
	Bands of rock and clay	6	1	373	2
	Hard rock [light grey oolitic limestone, freestone at 375 feet]	4	6	377	8

	Boring at Oxford.	Thickness.		Depth.	
		Ft.	in.	Ft.	in.
[Upper Estuarine Series, 28½ feet]	Bands of rock and clay [grey and black carbonaceous clay, silt or black mud, and a few thin beds of marl and rock, with shells, iron pyrites, "beef," black wood and other vegetable matter] [Sandy marl, greenish, *Ostrea Sowerbyi*, *Rhynchonella subtetrahedra*, Echinoderm spine at 378 feet Thin bed of grey clay (fuller's earth), at 379 feet Sandy marl, greenish, *Ostrea Sowerbyi*, *Perna* sp., *Hinnites*, *Mytilus* sp., *Placunopsis socialis* ? M. and L., at 380 feet Thin bed of dark grey oolitic shelly rock and greenish and grey sandy marl, *Ostrea Sowerbyi*, at 382 feet Blackish-grey clay, slightly sandy, with shells, iron pyrites, and thin irregular bands of "beef" at 386 feet Black silty clay with shells and iron pyrites, *Cyrena* ? at 390 feet Small bivalve shells, pyritous, (valves united) in black clay, with many pellets or little spherical grey stones, the size of large shot, *Cyrena* ? at 395 feet Black shelly clay and marl: very thin seams of brown and whitish sand, and black laminated carbonaceous shale with lignite at 396 feet Black sandy shale with concretions and wood (? piece of branch) and other vegetable matter, and iron pyrites at 398 feet Small irregular-shaped fragments and nodules of light mottled pinkish and grey hard limestone in black clay, with seams of brown sand, at 402 and 404 feet Black papery carbonaceous shale, very friable, seemingly composed of strap-like leaves, longitudinally striated, and iron-pyrites at 404½ feet Hard blackish-grey oolitic stone 4 inches thick, at 405 feet Black shaly clay and marl at 405½ feet]	28	6	406	2

	Boring at Oxford.	Thickness.		Depth.	
		Ft.	in.	Ft.	in.
[Inferior Oolite, 16⅓ feet]	Hard rock, [hard blackish-grey coarse oolitic shelly limestone, presenting a vesicular appearance, and containing lignite, at 406 feet 2 inches ; passing down into light and dark grey ragged and coarse oolitic limestone rock, with yellow, buff, and brown oolitic grains, and very shelly throughout, to 419 feet (12 feet 10 inches in thickness) ; the above merging in a very irregular manner into intensely hard dark grey shelly compact limestone, almost entirely devoid of oolitic structure, 3 feet 6 inches in thickness. *Terebratula* sp., *Pecten demissus. Mytilus* sp.]	16	4	422	6
[Lower Lias, 17 feet]	Blue clay. [Bluish-grey and light grey micaceous clays and marl, with shells in places. A good specimen of the Ammonite *Amblycoceras capricornu* was obtained in light grey clay at 431 feet. White opaque and transparent spar, and iron pyrites occur in its chambers]	17	0	439	6

The Valley Gravel overlying the Oxford Clay contained a large quantity of water. When the Oxford Clay had been bored through, some water was found in the Cornbrash. It was anticipated that a supply of water would have been obtained from the Great Oolite, but a feeble supply only of water rose from a depth of 402 feet to within 3 feet of the surface of the ground on the 28th March, 1898. The water previously met with had risen to 17 or 19 feet.

The total solid matters in the water from the depth of 400 feet were given as 672 grains per gallon, by Mr. W. W. Fisher. Calculated as constituents in combination, the results of his analysis were stated by him to be as follows [1] :—

	Grains per gallon.
Sodium chloride	286·0
——— sulphate	323·9
Magnesium sulphate	18·0
Calcium sulphate	11·42
——— carbonate	28·0
Silica (and Fe_2O_3)	1·19
	668·51

Mr. R. G. Bell, the Manager of the City Brewery, stated, Jan. 20, 1899, in a note to Mr. Blake, that he was "rather of opinion that the top gravel water was not entirely shut off, but the admixture of it with the lower very saline water was probably slight." In another note, Jan. 18, 1899, he remarked that "the composition of the solids is very similar in all our wells at the brewery, and also in the Brewer Street water from the same gravel, distant about 100 yards from the brewery. These waters are not used for brewing, but only for refrigerating purposes."

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[1] *The Analyst*, Feb., 1904.

The following analysis was kindly furnished to Mr. Blake by Mr. Bell.

Analysis by Dr. G. Harris Morris of water from Valley Gravel, 25 to 30 feet thick, overlying Oxford Clay at the City Brewery, Oxford, May 14, 1898:—

	Grains per gallon.
Sodium chloride	7·73
Potassium sulphate	14·07
Calcium nitrate	9·02
——— sulphate	15·37
——— carbonate	31·68
Magnesium sulphate	7·86
Silica and alumina	1·96
	87·69

Mr. W. W. Fisher remarks that "the study of Oolite waters leads to the general conclusion that the uncovered beds of limestone yield calcareous waters of a hard character, while the deep beds, and especially the beds covered by clay, yield saline or alkaline supplies."[1] He expresses the opinion that the constituents are derived from the rocks traversed by the water, the more saline of which occur where they are subject to little or no movement. This explanation does not seem wholly satisfactory; at any rate, if long-continued pumping does not decrease the salinity, we may admit the possibility of deep-seated sources, where the increased temperature of the waters has facilitated solution.[2]

Kellaways Beds.

Water, though seldom of good quality, is found in places in the Kellaways Beds at the base of the Oxford Clay. They comprise alternations of sands, sometimes with doggers, and loams and clays, so that they cannot be depended upon for any large supply of water. As a rule there is about 10 or 12 feet of clay at the base of the Kellaways Beds, separating the more porous strata from the Cornbrash.

Corallian Beds.

The Corallian Beds yield useful supplies of water in many localities. Phillips stated that near Oxford the Lower Calcareous Grit is about 60 or 70 feet thick, and that "the sand is sometimes so loose as to be 'quick,' and choke the wells, which in many places are sunk to it through the superincumbent rock and clay."[3]

CHAWLEY, by Cumnor.

Wells 50 to 57 feet deep in Coral Rag and Calcareous Grit.

One well 55 feet deep, 5 feet of water. Analysis showed 39 grains per gallon of solids. Information from Mr. W. W. Fisher.

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[1] *Analyst*, Feb., 1904.

[2] See H. B. Woodward, "Jurassic Rocks of Britain," v., p. 342.

[3] Geology of Oxford, &c., p. 298.

KENNINGTON.

Well made in 1902, near the village, 56 feet to water. Communicated by Mr. E. English to Mr. W. W. Fisher.

Another well at Golf Links, made in 1904 by Mr. E. W. Allfrey, 48 feet deep. 15 to 20 feet of Coral Rag with hard rock at bottom, sand below. The well contained 2 feet 3 inches of water, but was afterwards deepened.

Analysis showed 35 grains of solids per gallon. Information from Mr. W. W. Fisher.

COTHILL, N.W. of Abingdon.

Made by Messrs. Isler, 1903, for Cothill School.

Communicated by Mr. George Winship Borough Buildings, Abingdon.

Height above O.D. about 218 feet.

No supply was met with.

		Thickness.		Depth.	
		Ft.	in.	Ft.	in.
Corallian	Red sand and rock	7	6	7	6
	Grey rock	4	10	12	4
	Red sand and rock	3	8	16	0
	Rock	0	9	16	9
	Blue rock and pebbles	1	3	18	0
	Blue sandy clay	13	6	31	6
	Blue rock	1	4	32	10
	Blue rock and blue sandy clay ...	1	6	34	4
Oxford Clay	Blue sandy clay	87	0	121	4

RADLEY COLLEGE.

1. Well sunk 100 feet. Details communicated to Mr. T. I. Pocock by the Warden (the Rev. T. Field, D.D.).

		Thickness.	Depth.
		Ft.	Ft.
	Gravel	12	12
Kimeridge Clay	Clay	30	42
	Clay and rock	34	76
Corallian	Rock	24	100
	Sand with water.		

2. Well sunk 81 feet; the rest bored. 220 feet above Ordnance Datum. Communicated by Messrs. Duke and Ockenden to Mr. C. E. Hawkins.

		Thickness.	Depth.
		Ft.	Ft.
Kimeridge Clay.	Clay	81	81
Corallian	Sand and rock	16	97
	Hard rock	4	101
	Sand with water	6	107
	Hard rock	5	112
	Sand and clay	1	113

ICKFORD.

Wells, 37 or 38 feet deep, obtain water from a "stone-layer," which, how-ever is not always present. It is about 15 feet down on the eastern side of the village. Water is also obtained in shallower wells from fine gravelly beds of no great thickness, and from soakage through soil of gravelly loam.

OAKLEY

Wells mostly up to 20 feet deep in main part of village. No water in well at Oakley Wood Farm. North of Foresters' Arms, Oakley Common, there is a well that is said never to fail. At Little London a well was sunk about 40 feet, and a good supply of water was obtained. At Manor Farm a well sunk about 30 feet has yielded a plentiful supply.

Near Oakley the wells probably derive supplies from the cherty rock in the Lower Corallian at the base of the Ampthill Clay.

WORMINGHALL.

The wells are not more than 15 feet deep, but as a rule there is a sufficient supply of water.

Portland Beds.

These strata yield important local supplies of water at varying levels. (See p. 54.)

In Shotover Hill a clay-bed separating the Upper and Lower Portland Beds throws out springs along the upper slopes, but the more copious springs issue from the lower slopes at the junction of the lower sandy strata and the Kimeridge Clay.

To the east and north-east the Lower Portland Beds pass from sands to clayey sands and sandy clays, and the chief springs are then thrown out at the base of the Upper Portland stone-beds, as at Brill.

Brill is surrounded by a number of fairly strong springs, but owing to imperfect sanitary arrangements in the village, the waters have become more or less contaminated.

In other localities, as at Great Haseley, old stone-pits have been utilized for the reception of village rubbish, a proceeding not calculated to improve the supply of water derived from the strata in the neighbourhood.[1]

Lower Greensand.

Boars Hill.—Water is obtained from the Ironsands, and is held up by the Kimeridge Clay. The wells are from 35 to 45 feet deep. In seeking water the uneven surface of the clay underlying the sand has to be taken into account. Where the clay rises in level no water may be obtained, while at an adjacent spot where it forms a hollow a good supply may be found.

Valley Gravel.

The Valley Gravels in various localities yield supplies of water, but these, of course, are liable to contamination in areas that are much populated.

At Abingdon, according to Mr. J. H. Blake's notes, the old town wells were 12 to 14 feet in depth. Others at Eynsham are about the same depth. Those at New Hinksey, as noted by Prestwich, were from 10 to 16 feet deep.

The original supply of water to Oxford was obtained from wells sunk in the Valley Gravel, which varies from a few feet to 30 feet in thickness. (See p. 125.)

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[1] See H. B. Woodward, *Journ. Royal Sanit. Inst.*, xxvii., 1906, p. 467.

John Phillips remarked that "the deep bed of gravel which makes the foundations of the higher parts of this city, furnishes clear water at almost every point where a well can be sunk; and it hardly ever happens that these are dried. Before so many wells were sunk—one to almost every house in the more favoured parts of Oxford—natural springs of considerable strength discharged the overflow of the never-ceasing supply which, falling in rain or melting in snow, filled the gravel from Summertown to the Quadrangle of Christchurch. One of these, still flowing on the western side, and another, formerly discharging on the eastern side, were perhaps the greatest of these springs—truly 'Holy Wells.' . . . The water so issuing by natural orifices was not pure in the chemical sense; it contained much carbonate and some sulphate of lime gathered by the rain in its percolation through the calcareous gravel and its slow current on the subjacent clay. But it was not otherwise contaminated."[1]

The springs noted by Prestwich are one formerly existing at Holywell, one in the deer park of Magdalen College, the Walton-well spring near the canal bridge leading to Port Meadow, and others that feed Worcester College lake.

In the course of time, owing to the growth of the city and the imperfect sanitary arrangements, many of the wells became polluted, and as early as 1610 some of the colleges were supplied by pipes from a spring that issues from the Corallian rocks above North Hinksey. At that time also a fountain for public use was erected at Carfax Cross. The spring (in 1876) contained about 25 grains of carbonate of lime per gallon. Many years afterwards public water-works were established, the source of supply being the river below the town. "In consequence of the pollution of the water. arising from the extension of manufactories, from gas-works, and local drainage, the intake of the water was removed in 1855 from the river to a small artificial lake, formed in the valley at New Hinksey by a disused railway ballast-pit, about a quarter of a mile below Oxford."[2]

Mr. R. H. Tiddeman informs us that the ballast-pits to which Prof. Prestwich referred are still held in reserve in case of emergency, but the ordinary supply is drawn by pipes from the Isis at King's Weir, about a mile N.N.W. of Godstow. Thence the water goes by gravitation to the Waterworks at New Hinksey, and is filtered and pumped to a reservoir on Headington Hill on the south side of the road. A later reservoir has been added for the supply of the higher ground, and this is situated on the north-west side of Shotover Hill.

BUILDING-STONE.

Various local stones from the Great Oolite, Forest Marble, Corallian Limestone, Calcareous Grit, and Portland Beds, have been and are still employed for building-purposes, but there is no freestone of first-rate quality in the area. Indeed, Oxford itself supplies a bad advertisement for the purely local stone. That which has proved most durable was obtained from the Great Oolite outside the limits of our area.

As remarked by Prof. Hull: "The freestone at Tainton Quarries has furnished the stone for some of the oldest buildings in Oxford, viz., those of the 12th, 13th and 14th centuries, and is still in good preservation; the mouldings being sharper and less weathered than of some buildings of the 17th and 18th centuries, which are cut out of blocks from Headington Hill quarries, near Oxford."[3] Thus Taynton stone has been used in the ancient parts of the Cathedral (Christ Church), in Merton College and Chapel, also in Blenheim Palace. The Clipsham Stone (Inferior Oolite) from Clipsham, in Rutlandshire, was used in 1889 in the new buildings of Brazenose College.

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[1] Geology of Oxford and the Valley of the Thames, pp. 500, 501.

[2] On the Geological Conditions affecting the Water Supply to Houses and Towns, with special reference to the modes of supplying Oxford. 8vo. Oxford, 1876.

[3] See Hull, Geol. of the country around Cheltenham. *Mem. Geol. Survey*, p. 58.

Freestone of good quality is now largely quarried, beneath a considerable thickness of superincumbent strata, at Milton, near Taynton.

The Stonesfield Slate has been used in roofing many of the old buildings, but it is not quarried within the limits of the map.[1]

Beds of oolite and shelly oolitic limestone belonging to the Great Oolite Series are quarried for building-purposes at Bladon and Long Hanborough.

Among the Corallian rocks the Headington Stone (" Shotover Limestone ") east of Oxford, has been employed as a freestone, though it is for the most part exceedingly poor, many of the buildings in Oxford where it was used having come to a deplorable state of decay. The upper beds of impure comminuted shell-limestone were those so much used; but all the beds are very variable and shelly, false-bedded shelly limestone passes laterally into rubbly coral-rock; and there are layers of shelly sand and hard lenticular bands of grey oolitic limestone. In the village of Headington Quarry most of the better stone has been removed, but here and there old quarries have been re-opened. A layer of the " best stone " (of its kind) occurs near the base of the limestones, about five feet above the top of the sands of the Calcareous Grit.

According to Plot, stone from the Wheatley Quarries was used for some of the older buildings in Oxford[2]; it is a variable stone, but on the whole more durable than that of Headington. Tombstones were formerly made from the freestone at the Lyehill Quarries, Wheatley. In other localities, as at Marcham, Beckley, &c., building-blocks are obtained.

Prof. Phillips mentioned that "At Great Hazeley the Portland Stone has been quarried from ancient time, and it there furnishes a limited supply of better quality than usual for building, being of good colour and firm and equal texture, except for the shells, which, however, mostly lie in bands. A thick grey or greenish sand is at the bottom; over this the stony series, the lower part workable freestone, the top hard splintery limestone, two feet thick, much jointed, fit for roads and rough walling, called 'Curl.'"[3] This " Curl stone " was formerly used for chimney-pieces. It is a grey and somewhat gritty limestone with fossils.

Much of the better building-stone has been worked out in the neighbourhood of Great Haseley. (See p. 60.)

The cemented gravel of Church Hanborough and Stanton Harcourt, has been locally used for building-purposes.

LIME.

Lime for building and agricultural purposes is made from the limestones belonging to the Great Oolite, Corallian, and Portland Beds.

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[1] Memoir on Jurassic Rocks, iv., p. 484.

[2] Plot, Nat. Hist. Oxfordshire, 1677, p. 76.

[3] Geol. Oxford, &c., p. 417.

The white limestones in the upper part of the Great Oolite are burnt for lime, and as the layers vary in quality it is usual to mix them; these beds, alternating as they do with marls, are capable of yielding a strong lime.

An excellent white lime has been made at Whitehill Wood near Ashford Mill.

The Corallian Beds are employed in various localities—the lime from the coral-rocks being in some places of a stronger nature than that made from the more oolitic freestone.

The limestones of the Portland Beds have also been burnt for lime at Brill, near Wheatley, Great Milton, and Great Haseley.

ROAD-METAL.

The Coral Rag Limestone is used for foundations of roads, and occasionally for surface metal on bye-roads; but it is not good for heavy traffic. The Calcareous Grit is similarly used.

Locally the Cornbrash and Forest Marble limestones are employed; also the doggers or "sand-ballers," in the Portland Sands near Headington, and some of the harder Portland rocks elsewhere.

The main roads are now metalled with Hartshill quartzite, obtained by canal from Nuneaton. This is usually the best material; it forms a cleaner and smoother surface than the Clee Hill basalt, which is more expensive and binds less easily. The basalt lasts better but is more muddy: it does not crack and is good for tramways. Thames gravel is used as a binding material.[1]

SAND.

At Shotover Hill, in the Portland Beds, the coarse white gritty sands (with "sand ballers") are used for mortar, and the finer sands for moulding bricks, while a lower bed just above the Kimeridge Clay yields a soft mealy sand that has been used for moulding in iron-furnaces as "foundry loam."

The very fine silica sand in the Shotover Beds has been utilized in the preparation of scouring-soap.

BRICKEARTH.

Brick and tile earths are worked in the Oxford Clay near Oxford, and in the Kimeridge Clay at Headington and Wheatley. Many of the smaller pits that were at one time worked have been closed owing to their inability to compete with the larger brickyards. The fluviatile loam of the third terrace at Upper Wolvercot forms a good brickearth. This kind has not been observed elsewhere in the district, but there may be some on the third terrace north of Begbroke.

At Brill, where the lower Portland Beds pass down into the Kimeridge Clay, the higher portion (equivalent to the Hartwell Clay) furnishes a "mild earth" well adapted for brick-making, while below the clay is stiffer and suitable for making tiles and drain-pipes. In this neighbourhood the chief brickyard now opened is at the junction of Kimeridge and Ampthill Clays, to the east of Brill railway-station.

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[1] Information from the Office of the City Engineer, Oxford.

Brickearth has also been worked in the Shotover Sands at Great Milton, and in the Gault near Warpsgrove.

FULLER'S EARTH.

The occurrence of fuller's earth in the Shotover Sands has long been noted, but the quantity is insufficient to be of commercial value.

OCHRE.

R. Plot, in 1677, referred to the ochre of Shotover as "being accounted the best in its kind in the world, of a yellow colour and very weighty, much used by *Painters* simply of itself, and as often mix'd with the rest of their colours."

"They dig it now at *Shotover* on the *east* side of the *Hill*, on the right hand of the way leading from *Oxford* to *Whately*, though questionless it may be had in many other parts of it; the *vein* dips from *east* to *west*, and lies from seven to thirty feet in depth, and between two and seven inches thick; enwrapped it is within ten folds of *Earth*, all which must be passed through before they come at it."

He gave the following section:—

Turf.
Reddish earth.
Pale blue clay.
Yellow sand.
White clay.
Iron stone.
White and sometimes reddish Maum [malm].
Green, fat, oily kind of clay.
Thin iron-coloured rubble.
Green clay.
Iron rubble.
Yellow ochre { Stone ochre.
Clay ochre.

The Stone Ochre was found "ready for use as soon as 'tis dug." The "Clay ochre, which because of the natural inequality in its goodness, they wash and steep two or three days in water, and then beat it with clubs on a plank into thin *broad cakes*, of an equal mixture both of good and bad; then they cut it into squares like Tiles, and put it on hurdles laid on trestles to dry, which when thoroughly done 'tis fit for the *Merchant*."[1]

The "yellow ochre of good quality" was noted by John Phillips as but three inches thick. His section[2] may be compared with that above given. (See p. 69.) The ochre is no longer worked,

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[1] Natural History of Oxfordshire, pp. 56, 57.

[2] Geol. Oxford, &c., p. 414.

APPENDIX.

List of Principal Works on the Geology of the District.[1]

1677. Plot, Dr. R.—The Natural History of Oxfordshire. Fol. Oxford.

1699. Llhwd, E.—Lithophylacii Britannici Ichnographia. 8vo. London. 2nd Edition. Oxford, 1760.

1809. Young, A.—View of the Agriculture of Oxfordshire. 8vo. London.

1815. Kidd, Dr. J.—A Geological Essay. [Description of Oxford gravel, in Chap. 17.] 8vo. Oxford.

1819. Smith, William.—Geological Map of Berkshire.

1820. ——— ———Geological Map of Buckinghamshire.

——— ———Geological Map of Oxfordshire.

1821. Buckland, Rev. Prof. W.—Description of the Quartz Rock of the Lickey Hill . . . with considerations on the evidences of a Recent Deluge afforded by the gravel beds of Warwickshire and Oxfordshire, and the valley of the Thames from Oxford downwards to London. *Trans. Geol. Soc.*, vol. v., p. 506.

1823. ——— ———Reliquiæ Diluvianæ; or Observations on the organic remains contained in Caves, Fissures, and Diluvial Gravel, and on other geological phenomena, attesting the action of an universal Deluge. 4to. London. 2nd Edition. 1824.

1829. Conybeare, Rev. W. D.—On the Hydrographical Basin of the Thames, with a view more especially to investigate the causes which have operated in the formation of the valleys of that river, and its tributary streams. *Proc. Geol. Soc.*, i., 145—149.

1834. Mitchell, Dr. James.—On the strata of Quainton and Brill in Buckinghamshire. *Proc. Geol. Soc.*, vol. ii., pp. 6, 7.

1835. Daubeny, Dr. C. G. B.—[Analysis of the Mineral Spring lately discovered near Oxford.] *Proc. Geol. Soc.*, vol. ii., p. 204.

1836. Fitton, Dr. W. H.—Observations on some of the Strata between the Chalk and the Oxford Oolite, in the South-East of England. *Trans. Geol. Soc.*, ser. 2, vol. iv., pp. 103—388.

1839. Daubeny, Dr. C. G. B.—On a Saline Spring near Oxford. *Trans. Geol. Soc.*, ser. 2, vol. v., p. 263.

1848. Stacpoole, Andrew D.—Environs of Oxford, enlarged from the Ordnance Map; the Geological Survey and Sections by Andrew D. Stacpoole, M.A., Fellow of New College.

1851. Orlebar, A. B.—On the Geology of the neighbourhood of Oxford, within the limits of Mr. Stacpoole's map. *Proc. Ashmolean Soc.*, vol. ii., p. 253.

1858. Phillips, Prof. J.—On the Estuary Sands in the upper part of Shotover Hill. *Quart. Journ. Geol. Soc.*, vol. xiv., pp. 236—241.

1859. Hull, Prof. E.—The Geology of the Country around Woodstock, Oxfordshire. *Mem. Geol. Survey.* 8vo. London.

Sheet 13.—Oxford, Abingdon. *Geol. Survey.* London.

Sheet 45, S.W.—Woodstock, Witney, Eynsham. *Geol. Survey.* London.

1860. Hull, Prof. E.—On the South-easterly Attenuation of the Lower Secondary Formations of England; and the probable Depth of the Coal-measures under Oxfordshire and Northamptonshire. *Quart. Journ. Geol. Soc.*, vol. xvi., pp. 63—81.

Phillips, Prof. J.—Notice of some Sections of the Strata near Oxford. No. 1. The Great Oolite in the Valley of the Cherwell. No. 2. Sections South of Oxford. *Quart. Journ. Geol. Soc.*, vol. xvi., pp. 115—119, 307—311.

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[1] See also W. Whitaker, List of Works on the Geology and Palæontology of Oxfordshire, of Berkshire, and of Buckinghamshire.—*Rep. Brit. Assoc.*, 1882.

1861. Clutterbuck, Rev. J. C. — On the Course of the Thames from Lechlade to Windsor, as ruled by the Geological Formations over which it passes. *Rep. Brit. Assoc.* for 1860, Sections, p. 75.

Hull, E., and W. Whitaker.—The Geology of Parts of Oxfordshire and Berkshire. *Mem. Geol. Survey.* 8vo. London.

Whiteaves, Dr. J. F.—On the Invertebrate Fauna of the Lower Oolites of Oxfordshire. *Rep. Brit. Assoc.* for 1860, Sections, pp. 104—108.

————On the Oolitic Echinodermata of the Neighbourhood of Oxford. *Geologist*, vol. iv., pp. 174, 175.

————On the Palæontology of the Coralline Oolites of the Neighbourhood of Oxford. *Ann. Nat. Hist.*, ser. 3, vol. viii., pp. 142--147.

1863. Clutterbuck, Rev. J. C.—The Perennial and Flood Waters of the Upper Thames. *Proc. Inst. Civ. Eng.*, vol. xxii., p. 336.

Sheet 45, S.E.—Islip, Brill. *Geol. Survey.* London.

1864. Green, A. H.—The Geology of the country round Banbury, Woodstock, Bicester, and Buckingham. *Mem. Geol. Survey.* 8vo. London.

1867. Brodie. Rev. P. B.—On the Presence of the Purbeck Beds at Brill, in Buckinghamshire; and on the Superior Estuarine Sands there, and at certain places in Oxfordshire, &c. *Quart. Journ. Geol. Soc.*, vol. xxiii., p. 197.

Hull, Prof. E.—Horizontal Sections, Sheet 71. By Cuddesdon and Shotover Hill, Oxford, Stanton St. John, Islip, &c. *Geol. Survey.*

Morris, Prof. J.—On the Ferruginous Sands of Buckinghamshire, with Remarks on the Distribution of the equivalent Strata. *Geol. Mag.*, vol. iv., pp. 456--462.

1869. Thorne, James. — Excursion to Oxford. Reports of Excursions, Geologists' Association, 1869. [*Separately printed.*]

1870. Hull, Prof. E.—Horizontal Sections, Sheet 81. East of Abingdon, Boars Hill, Cumnor Hurst, Wytham Hill, to Pinsley Wood.

————and Prof. J. W. Judd. Sheet 82. From Handborough, near Combe, &c. *Geol. Survey.*

Perceval, S. G.--On the Occurrence of Schorl in Drift near Oxford. *Geol. Mag.*, p. 96.

1871. Phillips, Prof. J.—Geology of Oxford and the Valley of the Thames. 8vo. Oxford.

1876. Prestwich [Sir] J.—On the Geological Conditions affecting the Water Supply to Houses and Towns, with special reference to the modes of supplying Oxford. 8vo. Oxford and London.

————On the Mineral Water discovered in sinking the Artesian Well at St. Clement's, Oxford. *Proc. Ashmolean Soc.*

————Thickness of the Oxford Clay. *Geol. Mag.*, pp. 237—239.

1877. Blake, Rev. J. F., and W. H. Hudleston.—On the Corallian Rocks of England. *Quart. Journ. Geol. Soc.*, xxxiii., pp. 304—312.

1878. Jones, Prof. T. Rupert. — Notes on some Fossil Bivalved Entomostraca. [Describes six species from Shotover.] *Geol. Mag.*, pp. 103—110, 277.

1879. Prestwich, J.—On the Discovery of a Species of Iguanodon in the Kimeridge Clay near Oxford; and a Notice of a very Fossiliferous Band of the Shotover Sands. *Geol. Mag.*, pp. 193—195.

1880. Blake, Rev. J. F.—On the Portland Rocks of England. *Quart. Journ. Geol. Soc.*, vol. xxxvi., pp. 189—235.

Cobbold, E. S.—Notes on the Strata exposed in laying out the Oxford Sewage-farm at Sandford-on-Thames. *Quart. Journ. Geol. Soc.*, vol. xxxvi., pp. 314—320.

Hulke, J. W.--*Iguanodon Prestwichii*, a new species from the Kimeridge Clay. . . . *Quart. Journ. Geol. Soc.*, vol. xxxvi., pp. 433—456.

Prestwich [Sir] J.—Note on the Occurrence of a new species of *Iguanodon* in a brick-pit of the Kimeridge Clay at Cumnor Hurst, three miles W.S.W. of Oxford. *Quart. Journ. Geol. Soc.*, vol. xxxvi., pp. 430—432.

1881. Prestwich, Sir J.—An Index Guide to the Geological Collections in the University Museum, Oxford. 8vo. Oxford.

1882. ————On the Occurrence of the *Cyrena fluminalis* at Summertown, near Oxford. *Geol. Mag.*, pp. 49—51.

1884. ————A Letter on the Oxford Water Supply. 8vo. Oxford.

1885. ————Oxford Water Supply, Letters and Report. 8vo. Oxford.

1888. Bather, Dr. F. A.—Note on the Geology of Cumnor Hurst. *Journ. Oxf. Univ. Jun. Sci. Club*, vol. i., pp. 30—32.

1893. Blake, Prof. J. F.--Excursion to Brill. *Proc. Geol. Assoc.*, vol. xiii., pp. 71—74.

Woodward, H. B.—Jurassic Rocks of Britain, vol. iv. Lower Oolitic Rocks of England (Yorkshire excepted). 8vo. London.

1894. Dawkins, Prof. W. B.—The Probable Range of the Coal-Measures under the Newer Rocks of Oxfordshire and the Adjoining Counties. *Rep. Brit. Assoc.* for 1894, pp. 646—648.

Green, Prof. A. H.—Some Points of Special Interest in the Geology of the Neighbourhood of Oxford. *Rep. Brit. Assoc.* for 1904, pp. 644, 645.

Woodward, H. B.—Jurassic Rocks of Britain, vol. v. Middle and Upper Oolitic Rocks of England (Yorkshire excepted). [With Bibliography relating to Jurassic formations.] 8vo. London.

1897. White, H. J. Osborne.—On the origin of the High-Level Gravel with Triassic débris adjoining the valley of the Upper Thames. *Proc. Geol. Assoc.*, xv., pp. 157—174.

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1898. Salter, A. E.—Pebbly and other Gravels in Southern England. *Proc. Geol. Assoc.*, xv., p. 264.

Sollas, Prof. J.—The Influence of Oxford on the History of Geology. *Science Progress*, vol. vii. (N.S., vol. ii.), pp. 23—52; reprinted in "The Age of the Earth and other Geological Studies," 1905.

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1902. Blake, Rev. J. F.—Excursion to Headington, Shotover, and Wheatley. *Proc. Geol. Assoc.*, vol. xvii., pp. 383—385.

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Lamplugh, G. W.—Fossils of the Oxford Iron-Sands. *Geol. Mag.*, pp. 574, 575.

1904. Bell, A. Montgomerie.—Implementiferous Sections at Wolvercote (Oxfordshire). *Quart. Journ. Geol. Soc.*, lx., pp. 120—132.

Fisher, W. W.—On the Salinity of Waters from the Oolites. *Analyst*, Feb., 1904.

Healey, Maud.—Notes on Upper Jurassic Ammonites, with special reference to Specimens in the University Museum, Oxford. *Quart. Journ. Geol. Soc.*, lx., pp. 54—64.

Sollas, Prof. W. J., and Miss M. Healey.—Excursion to Cumnor. *Proc. Geol. Assoc.*, xix., p. 57.

1905. Lamplugh, G. W., and T. I. Pocock.—Notes on the Oxford Area. *Summary of Progress of Geol. Survey* for 1904, pp. 17—22.

Salter, Dr. A. E.—On the Superficial Deposits of Central and parts of Southern England. *Proc. Geol. Assoc.*, xix., pp. 1—56.

1906. Harmer, F. W.—Lake Oxford and the Goring Gap. *Geol. Mag.*, 1906, p. 470; *Rep. Brit. Assoc.* for 1906 (1907), pp. 572, 573.

Walford, E. A.—On some new Oolitic Strata in North Oxfordshire. 4to. Buckingham.

1907. Davies, A. Morley.—The Kimeridge Clay and Corallian Rocks of the Neighbourhood of Brill (Buckinghamshire). *Quart. Journ. Geol. Soc.*, lxiii., pp. 29—47.

————Excursion to Dorton, Brill, and Arngrove. *Proc. Geol. Assoc.*, xx., 183—186.

1907. Harmer, F. W.—On the Origin of certain Cañon-like Valleys associated with Lake-like Areas of Depression. *Quart. Journ. Geol. Soc.*, lxiii., pp. 470—513.

Newton, E. T.—Note on specimens of "Rhaxella Chert" or "Arngrove Stone" from Dartford Heath. *Proc. Geol. Assoc.*, xx., pp. 127, 128.

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